ENDEAVOUR
VOL 2
1943
G K V
HARDWAR

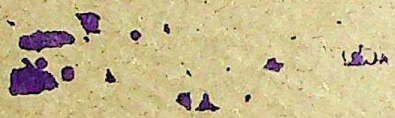
R
505
L84E
V.II

Gurukul Kangri C

mpal Foundation Cent

07818

Digitized by Arya Samaj Foundation Chennai and eGangotri



CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Karachh
JAWALAPUR

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

83407
6340

Digitized by Arya Samaj Foundation Chennai and eGangotri

सन्दर्भ ग्रन्थ
REFRENCE BOOK

यह पुस्तक वितरित न की जाय
NOT TO BE ISSUED

077818

अंक प्रमाणीकरण १९८४-१९८५

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

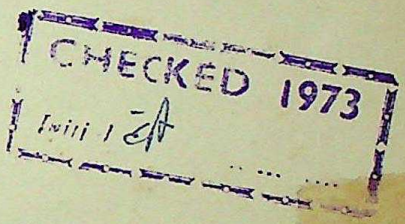
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

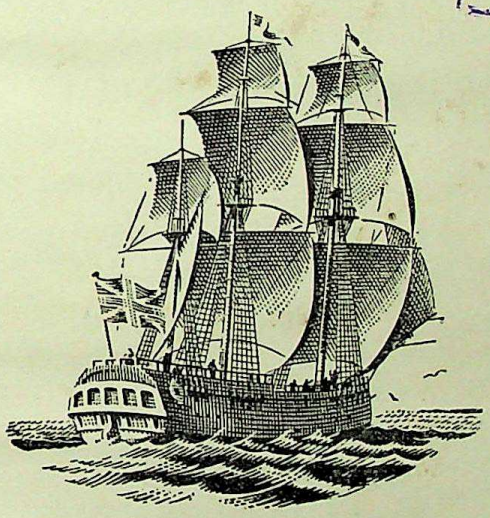
83407

Digitized by Arya Samaj Foundation Chennai and eGangotri

ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind





VOLUME II · 1943

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Endeavour

VOLUME II 1943

LIST OF ARTICLES alphabetically arranged under authors

Author	*Article*	*Page*
ALDINGTON, J. N.	The evolution of the electric lamp	62
BRAGG, SIR W. L.	Metals	43
BRITTON, H. T. S.	The electrometric determination of *p*H and some of its applications	148
BULLARD, E. C.	The earth's gravitational field	105
CRANE, M. B.	Cultivated plants of the past, present, and future	111
DAVIS, T. L.	The Chinese beginnings of alchemy	154
DINGLE, H.	Nicolaus Copernicus, 1473–1543	136
EDITORIAL	Chemotherapy	41
	Science and politics	1
	Science and the post-war world	83
	The seventeenth-century background	2
	Sound	123
FERGUSON, A.	Surface tension and its measurement	34
FRITSCH, F. E.	Forests of the sea	142
GORDON, W. T.	The chemistry of gemstones	99
HADDOW, A.	The production of cancer by chemical compounds	27
IMMS, A. D.	Locust invasions and their control	56
JEANS, SIR J.	The evolution of the solar system	3
LEVY, L., *and* WEST, D. W.	The development and use of luminescent substances	22
LYONS, COLONEL SIR H.	The Royal Society of London: Part I	12
	Part II	52
MATHER, K.	Mating discrimination in plants	17
MELLANBY, LADY	Vitamin D	73
QUASTEL, J. H.	Enzymes and their mode of action	85
RAWLINS, I.	Science in the service of the fine arts	93
THOMSON, SIR G. P.	The electron microscope	125
TODD, A. R.	The hemp drugs	69
WEST, D., *see* LEVY, L.		
WHITTAKER, E. T.	The aether: past and present	117

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

SUBJECT INDEX

Digitized by Arya Samaj Foundation Chennai and eGangotri

	Page
AETHER, The, E. T. WHITTAKER	117
ALCHEMY, The Chinese beginnings of, T. L. DAVIS	154
ARTS, Science in the service of the fine, I. RAWLINS	93
CANCER, Production of, by chemical compounds, A. HADDOW	27
CHEMOTHERAPY, EDITORIAL	41
CHINA, Research activities in	147
CHINESE beginnings of alchemy, The, T. L. DAVIS	154
COPERNICUS, Nicolaus, 1473–1543, H. DINGLE	136
CORRESPONDENCE:	
Lavoisier and contemporary British chemistry: D. MCKIE	84
Place of scientists in the community, The:	
SIR R. PICKARD, ALEX. FINDLAY, *and* SIR W. L. BRAGG	124
J. B. S. HALDANE	141
CULTIVATED plants of the past, present, and future, M. B. CRANE	111
'EARTH, Weighing the'	108
EARTH'S gravitational field, The, E. C. BULLARD	105
ELECTRIC LAMP, The evolution of the, J. N. ALDINGTON	62
ELECTRON MICROSCOPE, The, SIR G. THOMSON	125
ENZYMES and their mode of action, J. H. QUASTEL	85
FINE ARTS, Science in the service of the, I. RAWLINS	93
GEMSTONES, The chemistry of, W. T. GORDON	99
HEMP drugs, The, A. R. TODD	69
HYDROGEN-ION concentration, Electrometric determination of, H. T. S. BRITTON	148
LOCUST invasions and their control, A. D. IMMS	56
LUMINESCENT substances, The development and use of, L. LEVY *and* D. W. WEST	22
MATING discrimination in plants, K. MATHER	17
METALS, SIR W. L. BRAGG	43
*p*H, Electrometric determination of, H. T. S. BRITTON	148
PLANTS, Cultivated, of the past, present, and future, M. B. CRANE	111
PLANTS, Mating discrimination in, K. MATHER	17
REVIEWS:	
Absorption Spectra, Application of, to the Study of Vitamins, Hormones and Coenzymes, R. A. MORTON	81
Biochemistry and Morphogenesis, J. NEEDHAM	81
Cathode Ray Oscillograph in Industry, W. WILSON	162
Cellulose, An Introduction to the Chemistry of, J. T. MARSH *and* F. C. WOOD	40
Chemistry and Physiology of the Vitamins, H. R. ROSENBERG	160
Chromatography, Principles and Practice of, L. ZECHMEISTER *and* L. CHOLNOKY; *translated by* A. L. BACHARACH *and* F. A. ROBINSON	121
Colloid Science, Advances in, *edited by* E. O. KRAEMER, F. E. BARTELL, *and* S. S. KISTLER	161
Dictionary of Science, E. B. UVAROV	161
Entomology, Outlines of, A. D. IMMS	162

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

REVIEWS (*continued*): Page

Evolution: the Modern Synthesis, J. S. HUXLEY 39
Explosives, J. READ 39
Fuel Testing, G. W. HIMUS 122
Gases, War: their Identification, etc., M. B. JACOBS 80
High Polymers, *edited by* R. E. BURK, H. MARK, *and* G. S. WHITBY 121
Hydrogen Ions, H. T. S. BRITTON 82
Immunology, Fundamentals of, W. C. BOYD 121
Insects, Biological Control of, H. NICOL 122
Mathematics: its Magic and Mastery, A. BAKST 82
Modern Engineering, C. H. S. TUPHOLME 161
Physical Chemistry, A Treatise on, H. S. TAYLOR *and* S. GLASSTONE 122
Physics and Philosophy, SIR JAMES JEANS 80
Radio Receiver Design, Part I, K. R. STURLEY 162
Reproductive Capacity of Plants, E. J. SALISBURY 82
Science and Ethics, C. H. WADDINGTON *et al.* 162
Scientific Life, The, J. R. BAKER 40
Short-wave Wireless Communication, A. W. LADNER *and* C. R. STONER 40
Social Structure, H. A. MESS 82
Spectroscopy and Combustion Theory, A. G. GAYDON 80
Statistical Analysis in Biology, K. MATHER 122
Structure of Steel simply Explained, E. GREGORY *and* E. N. SIMONS 82
Textile Fibres under the X-rays, W. T. ASTBURY 162
Theoretical Organic Chemistry, J. B. COHEN 160
Twins and Super-twins, H. H. NEWMAN 82
Unknown Land, An, VISCOUNT SAMUEL 122
Voles, Mice, and Lemmings, C. ELTON 39
Volumetric Analysis, I: Theoretical Principles, I. M. KOLTHOFF *and* V. A. STENGER 161
War against Disease, M. SILVERMAN 82
War Gases: their Identification and Decontamination, M. B. JACOBS 80

ROYAL SOCIETY OF LONDON, SIR H. LYONS:
Part I 12
Part II 52

SCIENCE and politics, EDITORIAL 1
SCIENCE and the post-war world, EDITORIAL 83
SCIENCE in the service of the fine arts, I. RAWLINS 93
SEA, Forests of the, F. E. FRITSCH 142
SEVENTEENTH-CENTURY background, EDITORIAL 2
SOLAR system, The evolution of the, SIR J. JEANS 3
SOUND, EDITORIAL 123
SURFACE tension and its measurement, A. FERGUSON 34
VITAMIN D, LADY MELLANBY 73
'WEIGHING the Earth' 108

Made and printed in Great Britain at THE KYNOCH PRESS, *Witton, Birmingham, for the publishers,*
IMPERIAL CHEMICAL INDUSTRIES LIMITED, *London*, S.W.1
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

पुस्तकालय
गुरुकुल कांगड़ी विश्वविद्यालय
हरिद्वार

VOLUME II JANUARY 1943 NUMBER 5

Science and politics

In a book reviewed elsewhere in these columns, the thesis is postulated that 'there is only one aspect of politics which directly concerns scientists as such'—namely their freedom to pursue their own research. The belief that this freedom is of basic importance has already been expressed in ENDEAVOUR, and signs are not wanting that scientists are alive to the dangers of control as opposed to co-ordination. But to asseverate that, except in this respect, scientists should shun politics is to adopt a position wholly indefensible in the light of past events and future prospects. It rests on the tacit but unfounded assumptions that the sciences are extraneous to the rest of human activity and that there are wide regions in which scientific methods are not, and never will be, applicable.

Such assumptions are both pusillanimous and pessimistic. If there is one thing which science has unmistakably demonstrated, it is that the whole of the phenomenal world, including human nature, may confidently be expected to show itself rational in character and homogeneous with those parts of it—still comparatively few—which have already been investigated by scientific methods. With each advance of science a wider range of phenomena is woven into a harmonious pattern with those previously integrated, and there is no evidence that this process is approaching finality. It is indeed being markedly accelerated. Only if it were dwindling, only if there were plain indications that certain aspects of the world could never be embraced by science, would the divorce of scientists from politics perhaps become defensible.

Admittedly the time is distant when psychology will become an exact science, when ethics will become a science even of the most rudimentary kind, and when domestic and international politics will be inspired by the scientific method. But everything goes to show that, however remote, such an end is not inherently unattainable; and to recoil from a task because of present difficulties and future uncertainties is unworthy of the spirit and service of science.

There are, however, more immediate directions in which we believe the political duty of the scientist to be plain. In all parts of the world men and women with scientific training are profoundly dissatisfied with much of the prevailing government machinery. They see complete ignorance of, or indifference to, those principles of knowledge which, in the last two hundred years, have yielded more 'demonstrable truth' than was accumulated during the whole of man's previous existence. They see wilful distortion of fact, opinion swayed by prejudice or emotion, weighty decisions made upon the basis of scanty and often erroneous information. They see little of calm suspension of judgment, of inflexible purpose to advance step by step from the known to the unknown, of repression of the personal factor in reaching conclusions from ascertained data. Surely here are very real and very urgent reasons for action. If scientists withhold themselves from politics, in which they perceive so much that is wrong which they could help to improve, they are withholding the leaven that might leaven the whole lump.

Present conditions add insistence to another aspect of the matter. We see with sorrow and bitter resentment that the gifts of science are being perverted to cause death and destruction. The plea not seldom made by men of science that they are not responsible for the uses made of scientific knowledge cannot be accepted at its face value. It is sincere, but it evades a vital issue. Men who create knowledge that has immense power, either for good or for ill according to its use, have a special responsibility to exert themselves to the utmost in favour of the good and against the ill. In the circumstances in which

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

we live, this responsibility cannot be discharged if scientists are content merely to be in the world and not of it.

Scientists are not alone in wishing to be left in peace and quietness so that they may get on with their job. But it is within their capacity to make to the common weal a contribution unique both in present quality and in potentialities for the future. It is therefore clear that, before determining to stand outside the political life of his time, the scientist should searchingly inquire of himself whether such action is consistent with the discharge of his full duty to humanity.

The seventeenth-century background

The Royal Society of London, whose early history is recounted in this number of ENDEAVOUR by Colonel Sir Henry Lyons, holds undisputed pride of place among all scientific societies in the world. It was founded in the seventeenth century, a period which covers achievement of the first magnitude in physical science. The beginning of the century saw the first-fruits of the reaction against the decadent Scholastic philosophy; its later years witnessed the publication of the *Principia*—a work which raised the great structure of classical dynamics in a form which still serves, with few exceptions, for the interpretation of large-scale phenomena.

The part played by collective work in the development of seventeenth-century physical science is a major one. Francis Bacon had seen visions, and in his House of Solomon, the end of whose foundation 'is the knowledge of Causes and secret motions of things,' he describes a Utopian research institution with an imposing apparatus of underground workrooms, mountain observatories, biological stations, chemical, physical and physiological laboratories, all in charge of teams of workers—the Pioneers 'who try new experiments such as themselves think good,' the Depredators, 'who collect the experiments which are in all books,' the Merchants of Light, the Mystery-men, the Compilers, the Benefactors, the Lamps, the Inoculators, and the Interpreters of Nature, whose functions we leave the curious reader to deduce from their names.

In some of its ideals a forerunner of Solomon's House, the Accademia dei Lincei, at Rome, had a chequered existence which extended over the first half of the seventeenth century. Its successor, the Accademia del Cimento (1657–67), at Florence, set up a high standard of experimental philosophy. All the efforts of the academicians were directed towards 'experimentation, the creation of instruments, the establishment of standards of measurement and of exact methods of research.'

The Accademia del Cimento is long dead. Our own Royal Society, but a few years younger than the Accademia, still flourishes. It is strange that the Society should have its first beginnings, as Sir Henry Lyons tells us on another page, in a period the most disturbed in all British history. The quarrel between King and Parliament came to a head in 1642 and England was plunged into civil war. After swaying doubtfully for some years, the war ended in the defeat of King Charles I, and his execution in January 1649 ushered in an eleven years' republican interregnum and the Protectorate (we should now call it the dictatorship!) of Cromwell.

Yet through all these brawling years of civil strife and dissension, men 'inquisitive into natural philosophy and other parts of human learning, and particularly of what has been called *New Philosophy* or *Experimental Philosophy*,' met in London and in Oxford, and, in a planless way characteristically British, sowed the seed which developed into the Royal Society of London. Is there some influence in a period of war when, although (again to quote the words of Wallis) 'academical studies were much interrupted in both our Universities,' men's minds are quickened and turned to the increase of knowledge? It may be a coincidence, yet it has happened so frequently as to indicate a causal connection. If it be so, we see again that there is something of good even in the evil of war.

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The evolution of the solar system

SIR JAMES JEANS

The span of human life is so short that the solar system, except for its more obvious periodic phenomena, seems to us to be the same yesterday, today, and for ever. Yet it is subject to the universal flux, and its present form is the result of countless ages of change. Sir James Jeans offers an absorbing theory of its probable evolution.

The time is the year 1751, the scene a nobleman's house in East Prussia. The 27-year-old tutor to the family is reading a Hamburg periodical and happens upon a review of a book, *Original Theory or New Hypothesis of the Universe, founded upon the Laws of Nature, and solving by mathematical Principles the General Phenomena of the Visible Creation*, by Thomas Wright of Durham, England.

The tutor's name is Immanuel Kant. He feels a special interest in the British, claiming to be of British descent; his paternal grandfather, he says, was a Scot who spelt his name Cant. This may have resulted in his paying more attention than he would otherwise have done to the book of the unknown Englishman. In time he will be famous as the greatest of German philosophers, but at present he is more interested in science than in philosophy. He has, we may imagine, heard of various attempts to explain the visible creation in mathematical terms.

There was, for instance, Plato's belief that the distances of sun, moon and planets stood to one another in the ratio of the numbers 1, 2, 3, 4, 8, 9, 27—the so-called 'proportions of the double intervals.' There was the further idea, also attributed to Plato, that the planets had all been created at some enormously remote point in space—at infinity, as we should now say—and allowed to fall sunward from the hand of their Maker, the speed which each planet gained in its fall being changed into an equal transverse speed as soon as the planet reached its appointed orbit. This hypothesis accounted very simply for the rapid motions of the inner planets, but—as Newton showed in a later age—not for the speeds actually observed; the hypothesis could only be reconciled with these by supposing that the sun's gravitational force on each planet had been doubled at the moment when the direction of its motion was changed.

Again, there was Kepler's view of two thousand years later that the distances of the planets from the sun were determined by the geometry of the regular solids. He thought that if spheres were drawn round the sun, having the same diameters as the planetary orbits, then these spheres would be of such sizes that one of the regular solids—the cube, the tetrahedron, the octahedron, the dodecahedron and the icosahedron—would fit exactly between each pair of adjacent spheres, the inner sphere being inscribed in it and the outer sphere circumscribed around it. After thinking very highly of this theory for a time, Kepler abandoned it in favour of the view that the planetary distances stood to one another in ratios which were the frequency-ratios of harmonious musical intervals.

Kant saw at once that Wright's work contained something very different from this kind of mathematical fantasy. The English writer did not treat the astronomical universe as something for ever fixed, as Plato and Kepler had done, but as something for ever changing under the blows rained upon it by the passage of time.

Kant seems to have made no attempt to procure a copy of Wright's book—the state of his finances may have precluded that—but set to work to think out for himself in what way the operation of natural laws might have moulded the astronomical universe into its present form. In this way evolutionary concepts were introduced into the astronomy of the solar system—mainly by Kant, although Wright must at least be given the credit of having pulled a trigger very effectively.

Four years later Kant published the result of his meditations under the title *Allgemeine Naturgeschichte und Theorie des Himmels*, with the generous acknowledgment to Wright: 'It was reserved for an Englishman, Mr Wright of Durham, to make a happy step with a remark which does not

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

seem to have been used by himself for any very important purpose, and the useful application of which he has not sufficiently observed.' And, not having read Wright's book, he had further to confess that he could neither 'define the exact boundaries' between his own views and those of Wright nor point out in what ways he had advanced beyond Wright's sketch, and in what ways he had merely imitated it.

Kant pictured the primaeval universe as a chaotic cloud of specks of dust and particles of matter of various kinds, some standing at rest and others darting hither and thither in purely random motion. Such was the raw material out of which the operation of natural laws was to be made to fashion a universe of sun, moon and planets. Newton had contemplated much the same state of things some sixty years earlier, but there is no reason to suppose that Kant was acquainted with his conclusions. In a letter to Bentley, Newton had written:

> It seems to me that if the matter of our sun and planets, and all the matter of the universe were evenly scattered throughout all the heavens, and every particle had an innate gravity towards all the rest, and the whole space throughout which this matter was scattered was finite, the matter on the outside of this space would by its gravity tend towards all the matter on the inside, and by consequence fall down into the middle of the whole space, and there compose one great spherical mass. But if the matter were evenly disposed throughout an infinite space, it could never convene into one mass; but some of it would convene into one mass, and some into another, so as to make an infinite number of great masses, scattered great distances from one another throughout all that infinite space. And thus might the sun and stars be formed.

We shall return to the second of these alternatives later, for it describes the way in which we still imagine the sun and stars to have been formed, but it was with the former that Kant was concerned, and he reached much the same conclusions as Newton. He pictured order as gradually emerging out of chaos; the primaeval matter begins to cohere under the mutual gravitation of its parts, until finally the centre of the picture is occupied by a vast continuum which will ultimately figure as the sun. Kant thought that the mere act of cohering into a single body would set this mass into rotation, but here he went wrong. He further supposed that it would gradually cool, that as it cooled it would contract, that as it contracted it would rotate ever faster and faster, until finally its rotation became so rapid that it could no longer hold together as a single body, but burst like an overdriven flywheel. Masses of gas were thrown off from its equator and these, cooling still further, became first liquid and then solid. These solidified masses, according to Kant, formed the planets, of which our earth was one.

Forty years later the great French mathematician Laplace independently advanced what was practically the same hypothesis—independently, because he says that, so far as he knows, no one except Buffon had thought about these problems before himself. Laplace was an incomparably better mathematician than Kant, so that his theory is not only stated in better form than Kant's, but is also mathematically more accurate. Laplace knew better than to suppose that the mere act of condensing could set a nebular mass into rotation—for rotation cannot be generated out of nothing—and so postulated a nebulous mass which was in a state of rotation from the outset. This was in no way objectionable, for we know now—although Laplace did not—that most of the nebulae in the sky are in a state of rotation. Cooling, contraction, and speedier rotation now supervene, just as in Kant's theory. Laplace's keen mathematical insight next enabled him to trace out the further changes which were to be expected. He saw that, with increasing rotation, the mass would flatten out, its equatorial regions protruding more and more, until finally a ring of matter would detach itself from the equator and be left revolving round the ever-shrinking sun—and here Laplace pointed to Saturn (figure 1) with its encircling rings of matter as evidence that the state of things he was imagining could really occur in nature. Such an ejected ring of matter, he thought, would ultimately condense into a planet.

While this was going on, the central sun would still be cooling, contracting, and increasing its speed of rotation, so that after a time the same sequence of events would repeat itself and result in the birth of a second planet, to be followed in due course by a third, a fourth, and so on. Even this is not the end of the story, for the planets would themselves cool, contract and increase their speeds of rotation, just as their parent sun had done before them. Finally, by a small-scale repetition of the processes already described, families of satellites would be born to circle round the planets.

Laplace did not support his conjectures with detailed mathematical calculations, but a later

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

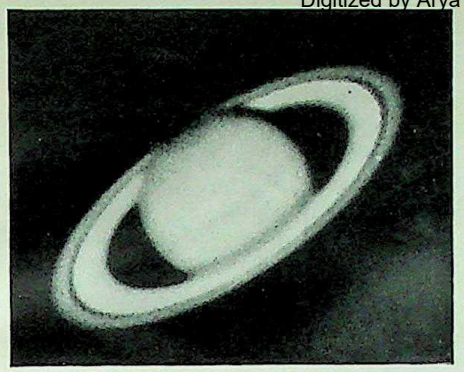


FIGURE 1 – *Saturn with its encircling rings. Laplace thought that the sun had thrown off similar rings which had ultimately condensed to form the present planets.*

FIGURE 2 – *The Great Nebula in Andromeda. This is one of the nearest of the extra-galactic nebulae. It is of about the same size and mass as our own system of stars bounded by the Milky Way, and contains enough matter to form about* 100,000 *million stars like our sun. Most of this appears to have already condensed into stars, and many of the types of stars—novae, variable stars, giant stars, and super-giants—which are familiar to us in our own system have been recognized in it.*

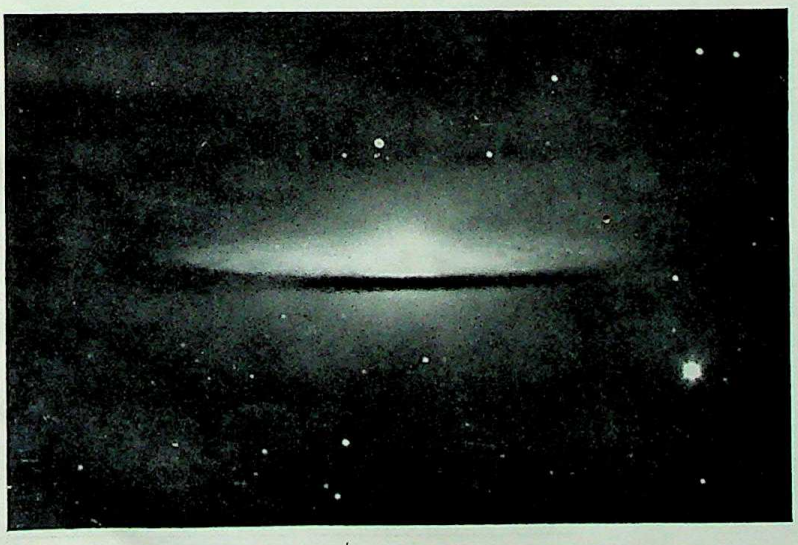


FIGURE 3 – *The extra-galactic nebula N.G.C.* 4,594 *in Virgo. Here we see the central flattened mass surrounded by a layer of cooler—or at least darker—matter in the equatorial plane of the nebula.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 4 – *The extra-galactic nebula N.G.C. 7,267. This is probably similar physically to the nebulae shown in figures 2 and 3, but is viewed from a direction perpendicular to its equatorial plane. The matter in its equatorial plane has already formed condensations which will produce, or more probably have already produced, clusters of stars.*

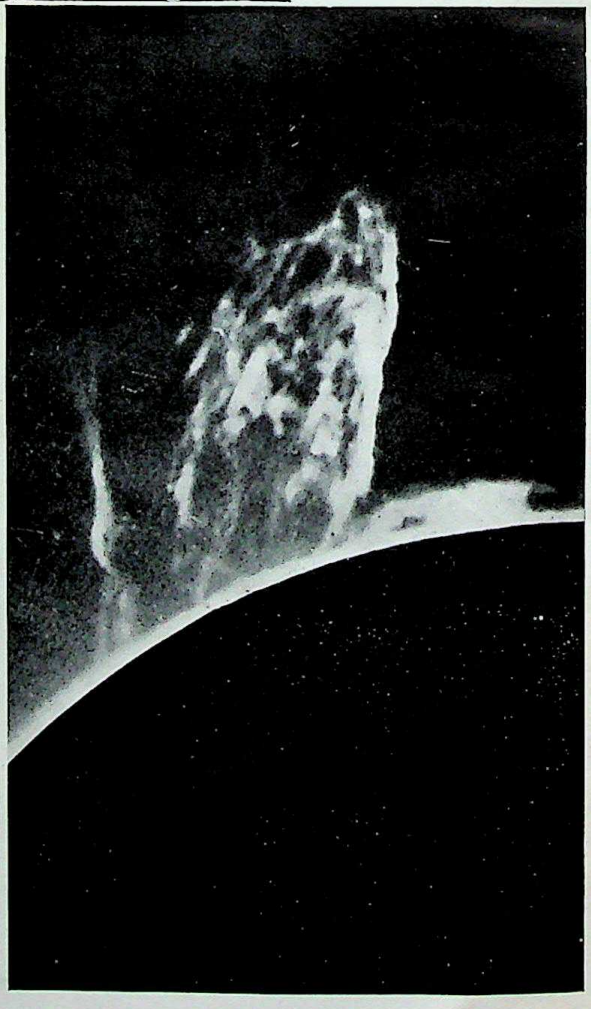


FIGURE 5 – *A huge solar prominence photographed by Evershed. The planetesimal theory imagines that in some past epoch far larger prominences were ejected by the sun and condensed into small solid bodies, by the aggregation of which the present planets were formed.*

generation of mathematicians has supplied these, and finds that all the processes imagined by Laplace are fairly true to life, provided that two conditions are fulfilled: the primaeval nebula must have been on a sufficiently ample scale, and must have been endowed with sufficient rotation to begin with. The first condition is fulfilled in the great extra-galactic nebulae (figures 2, 3, and 4), and the observed shapes of these are probably concrete illustrations of the sequence of configuration imagined by Laplace. But it is not fulfilled in an ordinary star. This is not on a large enough scale for Laplace's factors to operate, and when it breaks up from excess of rotation, it does not give rise to a family of planets; it more probably breaks into a 'binary system' consisting of two members, each of stellar size. The second condition—that of adequate rotation—is even more important since, as Babinet pointed out in 1853, it is quite impossible that the sun can ever have complied with it.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

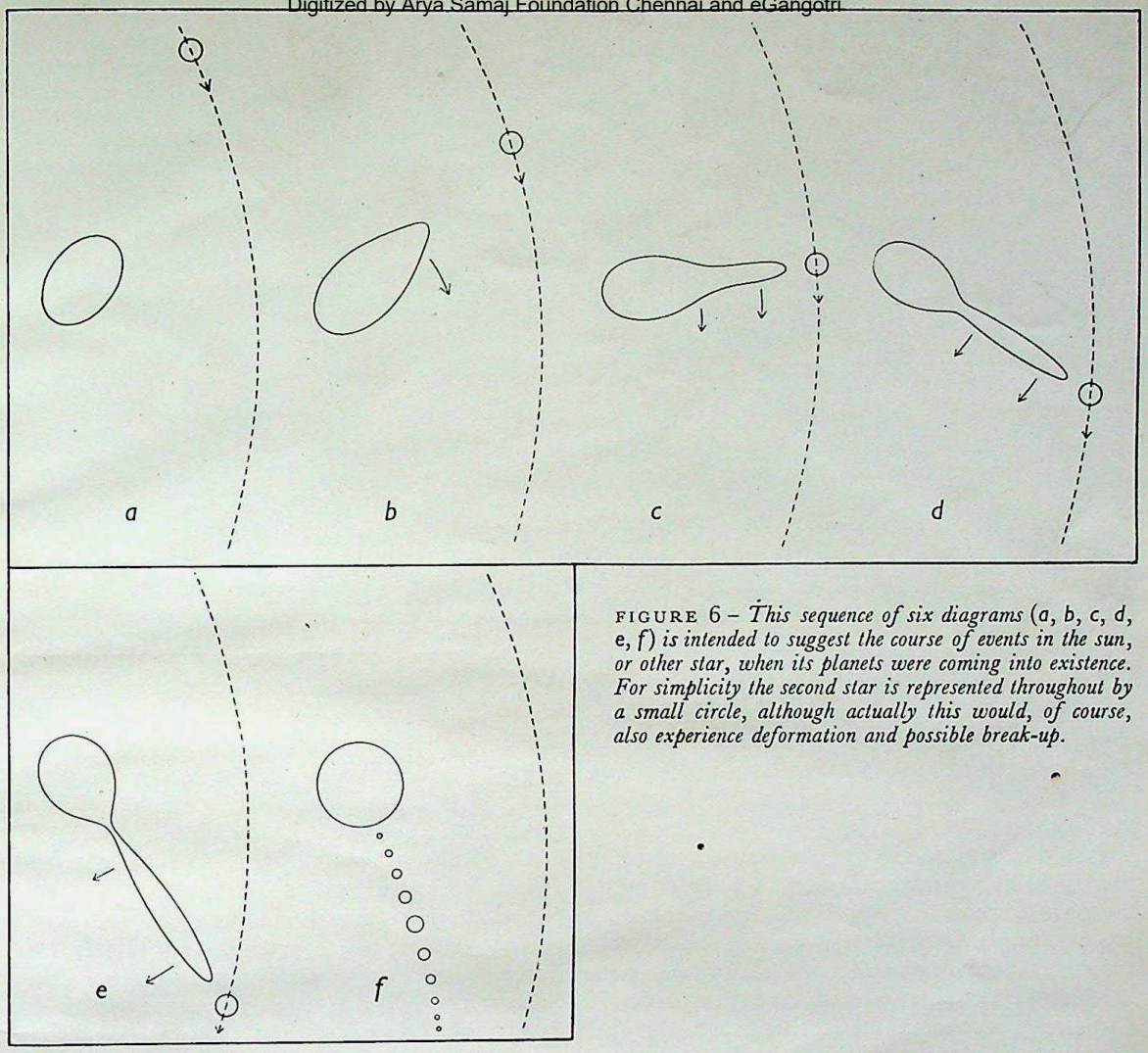
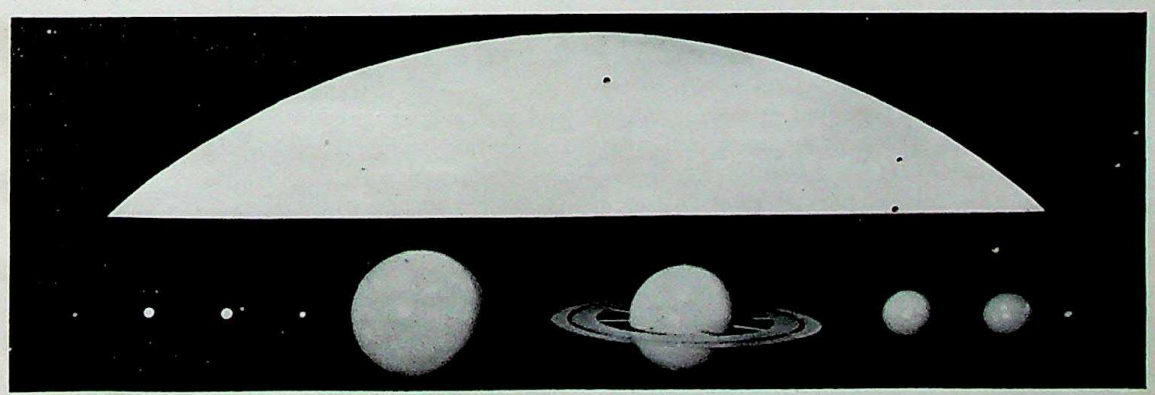


FIGURE 6 – *This sequence of six diagrams (a, b, c, d, e, f) is intended to suggest the course of events in the sun, or other star, when its planets were coming into existence. For simplicity the second star is represented throughout by a small circle, although actually this would, of course, also experience deformation and possible break-up.*

FIGURE 7 – *The planets drawn to scale as regards size, but not distance. The upper body represents part of the sun on the same scale. If the sun is supposed placed at the extreme left, the planets then follow in their proper order: Mercury, Venus, Earth (with moon), Mars, Jupiter, Saturn, Uranus, Neptune, Pluto.*



CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

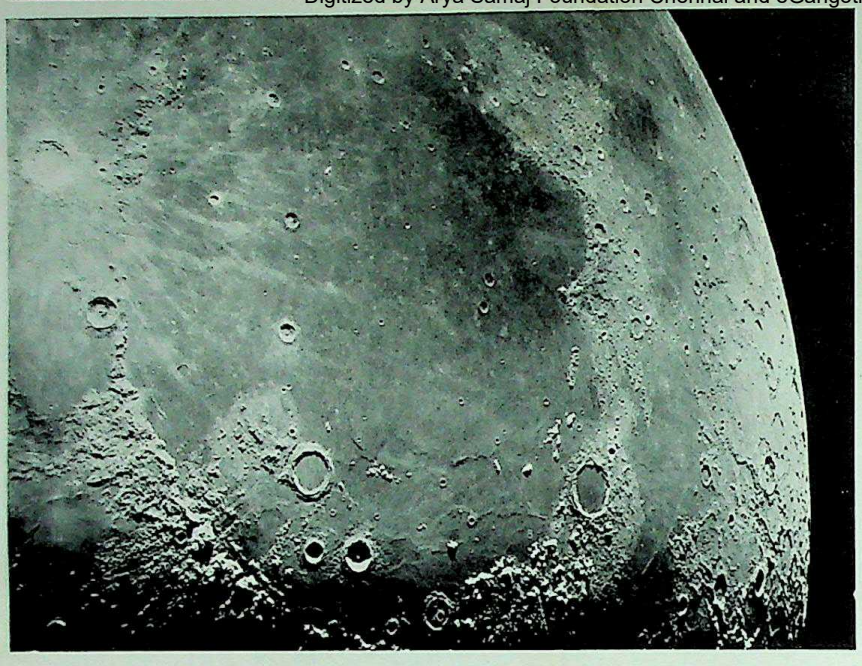


FIGURE 8 – *Part of the moon, showing the final product of the condensation of a mass of heated gas. The craters and vent-holes which cover the surface provide evidence of past eruptions of heated matter from the interior.*

For, throughout the whole sequence of changes imagined by Laplace, the system as a whole could never change the total amount of its angular momentum: whatever amount it had to start with, that it would retain to the present day. Because of this, it is easy to determine precisely what amount of angular momentum resided in the primaeval nebula—it was simply the total amount that we find today in the sun, planets, and satellites of the whole solar system.

Now this amount could not have effected even the first of Laplace's steps towards break-up. If we reconstruct the primaeval nebula by rolling all the members of the solar system into a single mass, which we then endow with this amount of rotation, we shall find no overdriven flywheel, but a mass rotating with such majestic slowness that its form is almost perfectly spherical; it will show even less flattening of figure than Jupiter does now.

Recent investigations have fully confirmed this objection, and have shown that it applies not only to Laplace's conjectures but also to every other conjecture which attributes the genesis of the planets to one star alone; it has now become abundantly clear that two bodies must have been involved—the planets must have had a father as well as a mother.

This is a conjecture which has often been made on its own merits. In 1750 Buffon imagined that the sun's family might have resulted from a collision between the sun and a passing comet, bits of the sun being splashed off and condensing to form the present planets. In 1860 Bickerton of New Zealand propounded a theory which was similar, except that Buffon's comet was replaced by a star and his head-on crash by a grazing collision: bits of the sun were scraped off by a passing star, and set spinning in the process. In recent years Jeffreys of Cambridge has returned to the same train of thought.

Yet a serious difficulty confronts all theories of this type. The two giant planets Jupiter and Saturn both possess extensive systems of satellites, and each planet with its satellites forms an almost exact replica, in miniature, of the main system of sun and planets. The systems of sun, Jupiter, and Saturn resemble one another so closely that it seems fantastic to attribute different origins to them. Yet we can hardly suppose that all three systems have been formed by grazing collisions; one collision which only grazes is a highly improbable event, and any theory which postulates three is simply asking too much.

In 1898, a Cambridge mathematician, W. F. Sedgwick, considered the possibility that the second body might produce planets without colliding with the sun at all, through tidal disturbances created in the sun. I put forward the same idea in 1901. In 1904 Chamberlin and Moulton, of the University of Chicago, suggested the same possibility independently and in far greater detail than I had done.

They imagined that in some remote past age

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

the sun had been liable to eruptions of the kind which now show themselves as solar prominences (figure 5), but of far greater intensity. While the sun was in this state, a wandering star happened to pass quite close to it. Its tidal action intensified the solar eruptions, puffs of gas being ejected with such speed that they broke clear altogether of the sun's atmosphere, and ultimately condensed into solid bodies out in space. To these the name 'planetesimal' was assigned, since they were of far less than planetary size; in time large numbers of them fell together, and by their aggregation the present planets were formed. But this theory suffers from the defect that puffs of hot gas of planetesimal size would not condense into solid bodies; their internal gas-pressure would cause them to expand, and they would merely scatter into space like the gas escaping from a leaky gas-burner.

In 1916 I tried to trace out the chain of events which would occur when a second star approached fairly close to the sun, and found that the tidal action of the second star might suffice of itself to break up the sun and produce a family of planets without calling in any intermediate mechanism such as eruptions of planetesimals. The process is briefly as follows:

Just as the proximity of the moon raises tides in our atmosphere, on our oceans, and even in the solid body of the earth, so the close approach of a second star would raise tides in the gaseous sun. But these tides would be very different from the minute tides which the moon raises in the earth. These are minute, partly because the moon is much smaller than the earth, and partly because it is at the relatively great distance of about sixty of the earth's radii away from the earth—and tidal effects diminish as the cube of the distance. But a second star, at least equal to the sun in mass, approaching to within two or three radii of the sun, would produce tidal effects which would be immense. Calculation shows that, in place of the mild elevation of surface we find in terrestrial tides, we should see a huge mountain of gas rear itself up on the sun as the other star approached, its rate of growth increasing almost without limit, until it ultimately darted out as a long tongue of gas—pulled out of the sun by the gravitational attraction of the second star and pointing towards the second star (figure 6 (*a-d*)).

Now any column of gas, provided only it is on a sufficiently large scale, is unstable through the operation of the process we describe as 'gravitational instability.' When a musician plays a flute, he sets the air inside it into vibration, slight condensations of air occurring at certain points with compensating rarefactions at others. As soon as he leaves off blowing, these inequalities of density disappear; the excess of pressure at each point of condensation causes the gas at this point to expand and all unevennesses are soon smoothed out. But if the flautist and his flute are on the astronomical scale, unevennesses are not smoothed out in this way; on the contrary, they continually increase. The reason is that, as the scale of size increases, a new physical factor becomes increasingly important, namely the mutual gravitation of the particles of the gas; this causes the gas to concentrate still more strongly round any points at which the density of gas happens to be above the average, no matter how slight the excess of density may be. Thus when irregularities of density once occur in a column of gas of astronomical size, they continue to increase until most or all of the gas is collected round the various nuclei of condensation. This is a small-scale version of the second of the two processes described by Newton in the letter already quoted, and to it the tidal theory ascribes the birth of the planets. We can calculate what would be the masses of the condensations formed under any specified physical conditions, and find that those formed out of the tidally deformed sun would have just about the masses of the actual planets.

Before these nuclei of condensation began to form in the column of solar gas, this would be shaped like a cigar or torpedo, one of the two pointed ends having formed the peak of the tidal mountain, and the other consisting of the last thin dribblings of matter which left the sun just as the tidal pull of the receding star was ceasing to be effective (figure 6 (e)). And when the condensations formed, we should expect to find the most massive occurring near the middle of the column, where matter had been most plentiful, and the least massive at the ends where matter had been most sparse. If the planets really are the remains of such condensations, we ought to find the most massive planets occupying positions near the middle of the sequence, with the smaller planets near to, and far away from, the sun. This is precisely what we do find. Actually Jupiter, the largest and most massive of all the planets, occupies the middle position in the sequence, and as we recede from this in either direction the planets fall off, both in size and mass, until we come to Mercury at the one extreme and Pluto at the other (figure 7).

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

These planets now move in almost circular orbits, but we know that this results from their having ploughed their ways for thousands of millions of years through the debris of gas and dust left by the cataclysm to which they owe their being. But when they first started their existences as detached masses, we may suppose that their orbits were of all kinds and shapes, possibly showing very little regularity beyond that of all lying in one plane—the plane in which the star had moved which had brought them into being. At times a planet would pass so near to the sun as to be broken by its tidal pull, just as its parent sun had been broken before it. Even the giant mass of Jupiter might suffice to break up a planet which wandered too near to it. In such ways as this we can imagine the systems of satellites being formed to circle round the planets, as well as the cloud of asteroids which occupies the planetary gap between Mars and Jupiter.

We may picture the new-born planets as cooling down, liquefying in whole or in part, and finally solidifying. Some of them might give birth to satellites while they were still in the gaseous state, others only after they had liquefied or even solidified. On the whole, the largest planets would be most likely to generate their satellites while they were still gaseous, for they would cool most slowly and so stay longest in the gaseous state. Thus the process by which they give birth to satellites is like that by which they were themselves born out of the sun, and we should expect them to produce systems which would be small-scale replicas of the solar system itself. But it is different with a planet which is already liquid or solid; mathematical investigation shows that the satellites produced by this will be fewer in number but larger in comparison with their parent planet. The gaseous planet produces many but small satellites, while the liquid planet produces few but large.

This accounts exactly for what we find in the solar system. The two largest planets, Jupiter and Saturn, cooling very slowly, would almost certainly still be gaseous when their satellite systems were born, and these, as we have seen, are almost exact replicas of the system of the sun. But of the smaller planets, some have no satellites at all, while others have satellites which are few in number but relatively large in size, and this is just the type of family to be expected for planets which were already largely liquid when their satellites were born.

The transition from one type of satellite system to the other occurs with Mars in the one direction and Uranus in the other. This suggests that Mars and Uranus were the smallest planets to remain gaseous for any length of time. If so, we can explain another feature of the solar system, namely the abnormal smallness of these two planets, both in size and mass, for their positions in the sequence of planets. For if these planets remained gaseous for a considerable time, they, with their feeble gravitational pulls, would obviously suffer more than the larger planets through the dissipation of their outer layers into space. Thus they may well be relics of far larger masses, and if we could restore their dissipated atmospheres, we might find the whole sequence of planets decreasing regularly in both size and mass as we receded from the central giant Jupiter.

Such is the tidal theory of the evolution of the solar system. It is based on *verae causae;* tides really occur in nature, so that some planetary systems must have been born in the way it describes. To the question as to whether our own planetary system was born in this particular way, the only answer is that the hypothesis that it was so born seems to account for a large number of the observed features of the system—too many, it may be argued, for the agreement to be purely accidental.

But the tidal theory occupies only one corner of a canvas on which we attempt to portray the evolution of the universe as a whole.

Let us imagine with Newton and Kant that the universe has evolved out of chaos, and let us try to reconstruct the primaeval chaos by imagining all the matter of the universe to be uniformly scattered throughout space. At present the matter is far from being uniformly scattered, most of it being aggregated in the detached units we describe as 'galaxies.' These comprise our own system of stars, bounded by the Milky Way, and a vast number of similar structures which we describe as 'extra-galactic' nebulae (figures 2–4). These nebulae are vast aggregations of stars, each containing about as much matter as 100,000 million stars like our sun. We speak of the amount of matter they contain rather than of the number of stars, because our knowledge is obtained by weighing the whole galaxy—by calculating its gravitational pull—and not by counting its stars, which would present an impossible task.

The average distance between galaxies is perhaps a million light-years, which means that

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

the average amount of matter per cubic metre of space is about 200 atoms of hydrogen or 1 atom of mercury.

If we could distribute all the matter of the present universe evenly throughout the whole of the present space, this is the density of matter we should obtain. But we must not assume that the primaeval chaos of perhaps 3,000 millions of years ago was of this same density. For it seems probable that space is expanding, and this at such a rate that its volume must have been increased a hundred-fold by 3,000 million years of expansion. If we assume that primaeval matter occupied only a hundredth part of its present space, and so had about a hundred times its present average density, and also that it consisted mainly of free electrons at a temperature not very far from that of melting ice, we find that gravitational instability would operate and divide the matter up into condensations, each of which would contain about as much matter as an average galaxy. Here, then, we have a very simple interpretation of the existence of these detached galaxies. We cannot, of course, be sure that they came into existence in the way we have described, but as before it seems unlikely that the agreement between theory and observation can be merely accidental.

We have already noticed that these galaxies have precisely the shapes which would be assumed by masses of gas in rotation, and in many of them rotation can actually be observed by spectroscopic methods. Thus it seems likely that the majority are in a state of rotation and, although we do not know what produced this in the first instance, it is clear that currents in the original matter might result in a slow rotation which would become intensified as the nebulae contracted. This would lead to the consequences that Laplace predicted, so that it is not surprising that the shapes of the nebulae fit on to the sequence described by Laplace.

At one point of this sequence a thin layer of matter has been thrown off, and lies, slowly rotating, in the equatorial plane of the nebula (figure 3). Here again gravitational instability must come into operation; the layer of gas would break up into condensations, and calculation shows that these would be of stellar mass. In this way, then, we can suppose the stars to have been formed: the nebulae were their birthplaces.

This brings us back to that corner of the picture which we have already described. The new-born stars contract, and ultimately form stars of the kind we know, a pair of them occasionally passing so close to one another that their tidal interaction produces a planetary system. The process of contraction must be exceedingly rapid; for a long time it was thought that its rapidity must be such that there could be no appreciable chance of planets being produced while it was in progress. But this overlooked that the immense size and tenuous texture of the new-born stars would make them especially susceptible to tidal action. Whatever the origin of our particular system may have been, it is reasonably certain that a large number of planetary systems have been formed through tidal action, and that a very large proportion of these were formed while their suns were still in a semi-nebulous state; this is a matter of mere statistical calculation. Our own system seems to carry intrinsic evidence that it was born in the same way as this majority—i.e. while the sun was still in a semi-nebulous state. For no other hypothesis can explain the immense extent of the system; if the planets had appeared when the sun had shrunk to about its present size, no available force could have taken matter out of the sun and set it revolving in the orbit of distant Pluto or could have made the planets rotate as rapidly as they now do.

When the planets were thought to have been produced by masses of the sizes of the present stars, it was clear that effective tidal encounters would be exceedingly rare events, whence it was concluded that planetary systems must be rare objects in the sky. It now appears that an additional and far greater number of effective tidal encounters must have taken place while the stars were large, so that planetary systems must be far commoner objects than was previously thought. What has happened to our sun is not the normal fate of a star, but it is much nearer to normal than we used to think, and it is a fate which must have befallen a fair proportion of the stars. And as the total number of stars is so great—being at the lowest computation greater than the number of blades of grass on the surface of the earth—it follows that the total number of planetary systems must be almost inconceivably great. Out of the vast total number, there must be millions which are almost exact replicas of our solar system, and millions of their planets must be almost exact replicas of our earth. Has life developed on these as it has here, and, if so, has it followed the same uneasy paths as our terrestrial life? We can only guess, for science has nothing to say on the question.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The Royal Society of London

Part I

COLONEL SIR HENRY LYONS

The Royal Society of London is by far the most celebrated scientific society in the world, and election to its Fellowship or Honorary Fellowship is a justly coveted distinction. Colonel Sir Henry Lyons has been engaged for many years in an exhaustive study of the history of the Society, of which he was formerly Foreign Secretary and later Treasurer. In the present article—the first of two—Sir Henry describes the birth of the Society and its early development.

On 15th July, 1942, the Royal Society had been in existence for 280 years since its first Charter was granted by King Charles II. The date of this Charter has been taken ever since as that of the Society's foundation, although the Philosophers' Society, which was formally constituted on 28th November, 1660, and six months later was named by the King's permission 'The Royal Society,' had been active for about 18 months when the Society received its incorporation by the Charter.

The influences which led to the foundation of the Society can be traced back in Britain for more than a century earlier, as the new or experimental philosophy spread rapidly among those who were studying natural science. The changes in intellectual outlook which had taken place in southern and western Europe during the fifteenth and sixteenth centuries exercised a notable influence on thought and learning in the seventeenth. Such men as Leonardo da Vinci, Copernicus, Galileo, and others had realized that greater certainty in the study of natural philosophy was attainable by research aided by experiments than by accepting what had been transmitted in the writings of earlier authorities. The new teaching spread widely, and in England William Gilbert of Colchester, physician to Queen Elizabeth and James I, investigated the attraction between magnets by means of a series of experiments which led him to the conclusion that the earth itself must be a great magnet; while William Harvey, who studied at Cambridge and afterwards at Padua, followed the new method of observation and experiment in the investigations which led him to the discovery of the circulation of the blood. About the same time Francis Bacon, Lord Verulam, was putting forward his views on how the advancement of knowledge might be utilized as so to bring about an improvement in man's conditions. His writings were widely read at Cambridge, where a number of learned men were taking an active interest in the progress of the new philosophy. About 1645, several of the younger men who had come under this teaching and influence began to meet in London to discuss the many problems which

The Hon. Robert Boyle.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

awaited solution, or at least serious study. One of the most eminent of them was Dr John Wallis, a divine and mathematician of distinction who graduated at Emmanuel College, Cambridge, and was ordained in 1640. He was at this time in London, since studies at the universities were much interrupted by the Civil War between King and Parliament; but he and about a dozen of his friends arranged to meet weekly if possible to discuss philosophical matters and to make experiments at Gresham College. During the next three or four years others joined them, to form what was known as the Philosophical or Invisible College; these included Dr J. Wilkins, who was Chaplain to the Elector Palatine; Dr J. Goddard, a physician and chemist; Dr C. Ent, a friend and supporter of William Harvey; the Hon. Robert Boyle, who had just returned from France; Dr W. Petty, a surgeon; and some others.

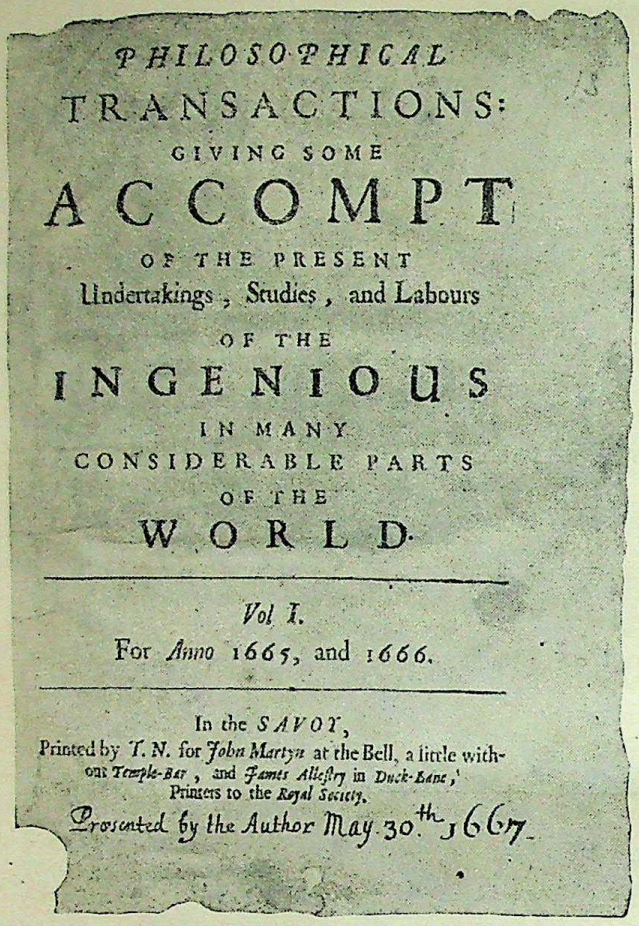
Dr J. Wilkins.

About 1648 several of their small company were transferred to Oxford. Wilkins was appointed Warden of Wadham College by the Parliamentary Party; Goddard was made Warden of Merton College, after being Physician-in-Chief to Cromwell in Ireland and Scotland; Wallis was appointed Savilian Professor of Geometry; and another Cambridge philosopher and mathematician, Dr Seth Ward, was appointed Savilian Professor of Astronomy. Robert Boyle, after his return from France in 1646, had retired to his house in the country to carry on his studies in chemistry; but in 1654, at the invitation of Wilkins, he took up his residence in Oxford, where he remained until 1668, when he moved to London. Thus it came about that from 1649 a group of the philosophers carried on their studies at Oxford for some years but continued to meet their colleagues at Gresham College whenever they had occasion to visit London.

After the restoration of the monarchy, the philosophers at Oxford and in London resumed their meetings at Gresham College, and on 28th November, 1660, a dozen of the most zealous of them agreed that they should form a scientific society to promote the new philosophy in this country. Sir Robert Moray, who had served both Charles I and Charles II and had been trusted by both, was chosen as being the most suitable of their number to inform King Charles II of their decision and of the aims of the Society. A week later he brought word from the Court that 'the King did well approve of this designe, and would be ready to give encouragement to it.' Thus the Philosophers' Society was founded, and about six months later the King approved a suggestion made to him by John Evelyn that the new Society should be known as the Royal Society. In the autumn of 1661 the philosophers submitted a petition to the King for a Charter of Incorporation, and this was granted on 15th July, 1662, thus providing them with a safeguard against the Society's suppression by opponents who soon became active. There were, however, some additional matters which the Fellows desired to have included in their Charter; they therefore prayed the King for a new Charter which should embody these additional provisions. This, the second Charter, was presented on 22nd April, 1663, and is the Charter by which the Society has always been, and still is, governed. In these Charters the administration of the Society and the direction of its policy are entrusted to a Council consisting of twenty-one Fellows of the Society, including the President and officers, who are elected annually at the anniversary meeting

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri



PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.

Vol. I.
For Anno 1665, and 1666.

In the SAVOY,
Printed by T. N. for John Martyn at the Bell, a little without Temple-Bar, and James Allestry in Duck-Lane, Printers to the Royal Society.
Presented by the Author May 30th 1667.

The title-page of the first volume of the Philosophical Transactions.

of the Fellows, ten of the councillors being replaced each year.

During the first ten years the Society prospered; the Fellowship rose to 215; a scientific periodical, the *Philosophical Transactions*, was first published in March 1665, and was at once recognized as the leading journal of its kind; meetings at which communications were received and discussed were held weekly. Foreign men of science occasionally attended these meetings and invariably expressed their admiration of the order and discipline which prevailed.

After the first few years of the Society's activity had passed, interest in it temporarily declined; membership fell off, and it was difficult to meet the expenses of publishing the *Philosophical Transactions*. When the Society accepted Sir Isaac Newton's *Principia* in 1686 and ordered its publication, there were no funds available to meet the cost until Edmond Halley undertook to provide the necessary sum. Indeed, from 1675 to the end of the century was a period of exceptional difficulty. Had it not been for the zeal and energy of Sir John Hoskins, a vice-president, and of Dr Hans Sloane, the senior secretary, the Society might not have weathered the storm. Although the scientific Fellows were few in number during the seventeenth century, they included a large proportion of eminent men; among these may be mentioned the mathematicians Barrow, Wallis, Newton, Gregory; the astronomers Halley, Flamsteed; the physicist Hooke; the chemist Boyle; the physicians Glisson, Goddard, Mayow, Lower; and the naturalist Ray.

In 1696 Sir Isaac Newton had been appointed Warden of the Royal Mint on the recommendation of Lord Halifax, and this provided him with an official post in London which brought him into closer contact with the Society and its Fellows. His great prestige as a leader of science indicated that he should be the Society's president, but it was well known that he would not accept nomination so long as Robert Hooke lived, since the latter's jealous criticisms and contentious claims for priority of discovery when others put forward any claim were more harassing than Newton's sensitive nature could support. Early in 1703, however, Robert Hooke died and Lord Somers, the president, at once announced that he did not desire nomination at the next anniversary meeting; Newton was therefore elected unopposed.

Nothing could have been more fortunate for the Society, for the new president's eminent position in the world of science greatly increased the esteem in which the Society was held. Newton did not restrict his activity to the routine duties of his new office, but gave his close attention to the administration. He attended the meetings of the Council most regularly—missing only fourteen of the 175 Council meetings which were held during his tenure of the presidency—and attended the ordinary meetings of the Society as regularly. He also introduced the practice that the Council meetings should be attended by both the secretaries instead of by one only. In these and other ways he greatly improved the efficiency of the administration and laid down a procedure which was followed with but trifling alterations for more than a century.

The number of scientific Fellows in the Society between 1663 and 1700 rarely exceeded fifty, and their subscriptions were not enough to meet its

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

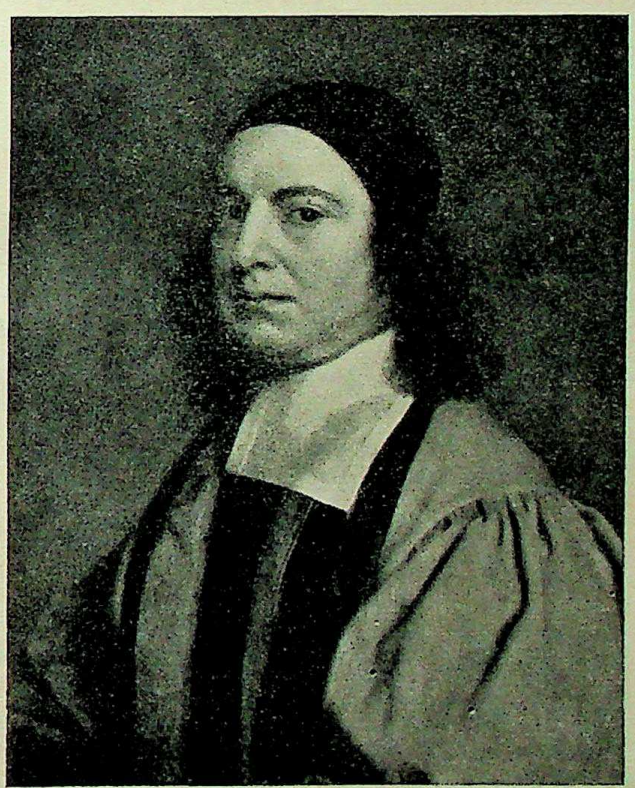
expenses. From the first, therefore, a number of candidates who had no scientific knowledge or interests were admitted, and these were usually twice as numerous as the scientists; they also were always in the majority on the Councils. This state of things did not tend to advance the scientific activity of the Society, but it was not until 1820 that scientific Fellows were in the majority on the Councils, and then, as we shall see later, the beneficial results of their influence were immediate and highly satisfactory.

In 1730 Newton's successor, Sir Hans Sloane, an administrator of much experience, instituted the practice of taking legal action against those Fellows who did not pay their subscriptions, and thus enabled the Council to put an end to the financial difficulties of the Society. From this time onwards the number of Fellows increased steadily, from 130 when Newton became president to 400 by 1775, and to 600 by the end of Sir Joseph Banks's presidency in 1820. The proportion of non-scientific to scientific Fellows, namely about two to one, varied little during the whole of the eighteenth century. Presidents like Lord Macclesfield and Lord Morton, both of whom were amateur astronomers of distinction, and Sir John Pringle, a well-known physician, notably advanced the scientific activity of the Society; but Martin Folkes and James West, who were antiquaries, did little in this direction. Towards the end of the century the secretaries were frequently historians and literary men, and in some years none of the officers was a man of science.

During the eighteenth century administration had not been conspicuously successful from the scientific point of view, but this came to an end with the presidency of Sir Joseph Banks, who guided the path of the Society for almost forty-two years. He was thirty-five years of age when he was elected president, the youngest of the Fellows who have held that distinguished post; he was a wealthy landowner, interested in botany, horticulture, agriculture, and the raising of stock; he had travelled extensively and had generously financed the collecting of plants, etc., from foreign countries with the object of acclimatizing them here or in British colonies. During most of his presidency, one of the secretaries, Dr Blagden, was a man of scientific training, but the treasurer and the other secretary were usually literary men; Banks himself, in spite of his general interest in agriculture and natural history, gave his attention mainly to the utilization of the plants and other specimens which his collectors and travellers brought or sent to him.

It is disappointing to find that he made no attempt to strengthen the Councils of the Society by the addition of men of science; on the contrary, the average number of them was often lower during his presidency than had previously been the case, varying from seven to ten out of the total of twenty-one. There is evidence that towards the end of his life he realized that the Society must take up a much stronger scientific position in the future than it had hitherto done, for he expressed the opinion that W. H. Wollaston, an eminent chemist, was the most suitable of the Fellows to succeed him (an opinion not without incidental interest, since it shows that Banks estimated Wollaston more highly than Sir Humphry Davy).

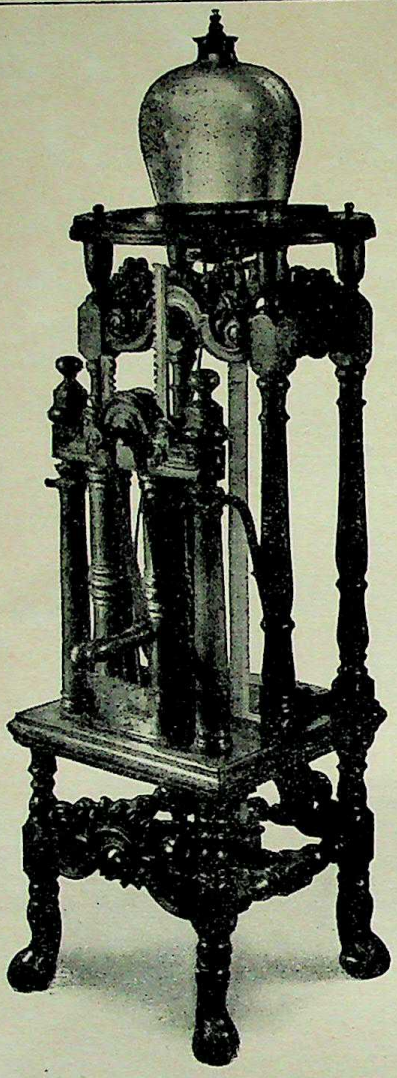
Sir Joseph Banks highly esteemed the honour which the Society had conferred upon him, and carried out his duties with the utmost regularity and thoroughness; he regarded the Society as a trust committed to his care and desired to preserve



Dr John Wallis.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

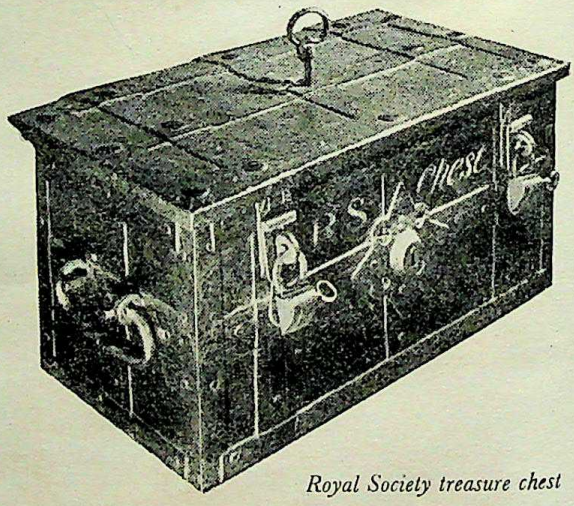
Digitized by Arya Samaj Foundation Chennai and eGangotri



Early air-pump

it as free as possible from any detrimental change or harmful competition. It was probably this which caused him to oppose the establishment of such specialized societies as the Geological Society and the Astronomical Society, which in each case was supported by a number of serious and distinguished workers convinced that the efficient study of their subject required greater facilities for discussion and publication than the Royal Society could provide. Subsequent experience has amply proved the correctness of their contention.

The very inadequate representation of science on the Councils of the Society in the eighteenth century must have greatly reduced the scientific influence which the Society might have exercised during those years; that such representation should hardly show any increase over a period of a century and a half is in itself extraordinary unless it can be ascribed to the deadening effect of a majority in the Councils which neither knew, nor cared to know, anything about natural science, and whose instinctive attitude was to obstruct any movement in favour of it. There were always a number of Fellows whose interests lay in advancing the knowledge of the branch of science which they had made their own; and these were the men who were devoting themselves to research as their own genius prompted them. Some of them served but seldom on the Councils, while others gave their time to this duty on many occasions—probably from a public-spirited desire to help the Society rather than from a preference for such work. The independent researches of the astronomers, mathematicians, chemists, physicists, physiologists, physicians, and others who made reputations for themselves by their scientific work at the same time enhanced that of the Royal Society. For its part, the Society took pride in publishing their discoveries in the *Philosophical Transactions* and in providing them with rooms where they could meet their colleagues. Among such Fellows the following may be mentioned:



Royal Society treasure chest

mathematicians: A. de Moivre, C. MacLaurin, J. Stirling; astronomers: J. Bradley, N. Maskelyne; physicists: S. Gray, H. Cavendish; chemists: J. Priestley, W. Wollaston; physicians: R. Abernethy, J. Mead, J. and W. Hunter, J. Lind, and J. Pringle. Many of these men made fundamental discoveries in their respective domains of science and medicine, and helped to establish the great scientific tradition to which the Royal Society owes its pre-eminent status.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Mating discrimination in plants

K. MATHER

The mechanism of pollination in flowers is a subject of perennial interest not merely to the professional botanist but to gardeners, horticulturists, and all lovers of plant life. Dr Mather shows that older interpretations were often too naïve, and that—for instance—many flowers apparently adapted to wind-pollination are in fact self-pollinated. The accompanying photographs show very clearly some of the ways in which plants effect discrimination in mating.

Pollination is the critical stage in the life of a flowering plant. If a pollen grain, after its release from the anther where it was produced, falls on to the stigma, or receptive surface, of the female part of a flower, it germinates to give a pollen tube. The tube then grows down the style until it reaches the ovary, where, provided that it has not been forestalled by other tubes, it passes into an unfertilized ovule. Each pollen grain carries a male generative, or sperm, nucleus which is discharged by way of the pollen tube into the ovule. Here the sperm nucleus fuses with the female egg nucleus lying in the embryo sac, to give a cell which develops first into an embryo, as found in the ripe seed, and later, if conditions are favourable, into a mature plant. The pollen also plays a part in the production of other seed structures, but this is ancillary to its main role in reproduction.

Thus pollination is like mating in animals—the essential precursor of fertilization and sexual reproduction. A seed-bearing plant which fails to be pollinated leaves no offspring. Similarly a pollen-producing plant leaves no progeny if its

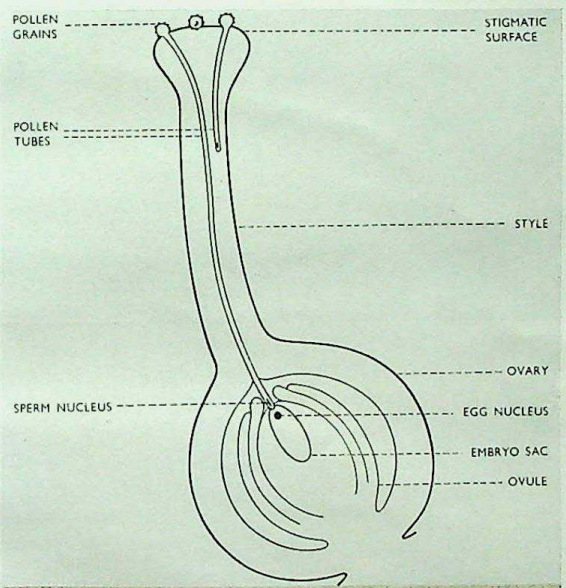


FIGURE 1 – *Pollination and fertilization. When a pollen grain falls on to the stigmatic surface it germinates to give a pollen tube, which grows down the style and penetrates into an unfertilized ovule. The sperm nucleus is carried down the tube and, when the latter reaches the ovule, passes into the embryo sac where it fuses with the egg nucleus to give a fertilized egg. Details of endosperm formation are omitted for simplicity.*

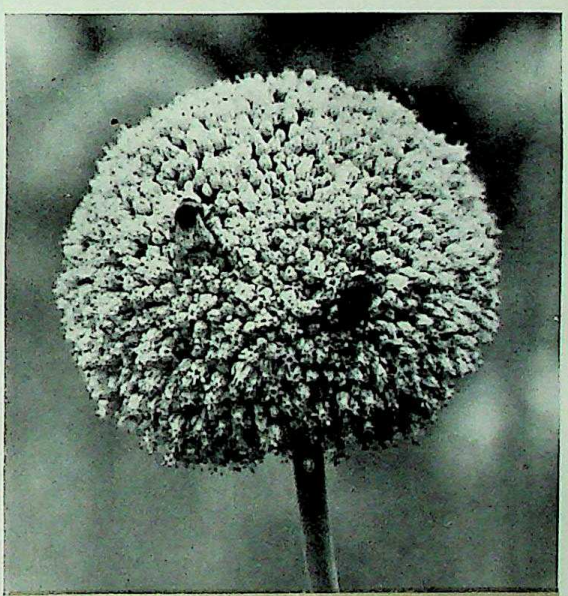
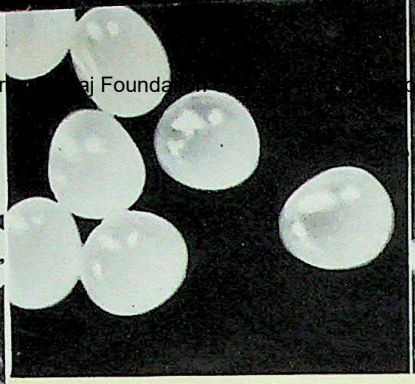


FIGURE 2 – *A flowering head of the leek* (Allium porrum). *Many flowers are massed together, so giving a striking head to which bees are attracted. Two bees can be seen working over the head. Some of the flowers are open and their anthers visible, but others are still closed. Anthers touch and deposit pollen on the under side of the bee, from which it is picked up later by stigmata. Pollen is thus transferred from flower to flower and plant to plant.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Ar[illegible]aj Founda[illegible]



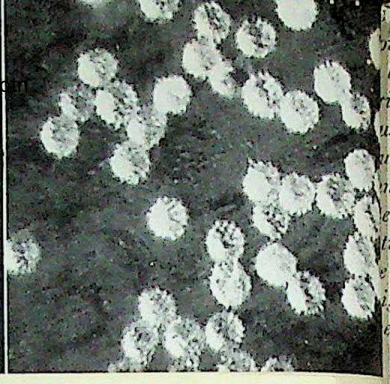


FIGURE 4 (*above*) – *Pollen grains of maize, on the left, and of the garden* (Dahlia variabilis) *on the right. Maize is adapted to wind pollination, its pollen smooth, dry and free running. Note how the smooth surface reflects high lights. Dahlia, the other hand, is insect-pollinated and its pollen is rough and sticky. The background shows traces of the sticky anther juice, which is also responsible for the somewhat blurred appearance of the individual grains.* (× 150.)

URE 3 (*above*) – *A plant of maize* (Zea mays). *Maize is adaptation to wind pollination. The flowers are unisexual, carrying the stamens being grouped into a 'tassel' at op of the plant. Anthers may be seen hanging from the l. The female flowers are grouped into ears which are lower down the stem. The ears are protected by husk s, from which protrude the stigmata, one to each flower, e form of long 'silks.' Two silks are visible in this . Pollen falls from the tassel and is blown about, some eventually falling on to silks. Pollen may, in this be transferred over considerable distances to other plants.*

URE 5 (*right*) – *In-bred and cross-bred maize. The in-bred ts in the foreground are very small and weak in comon with the cross-bred plants behind them. Maize is ted to cross-pollination and, in consequence, in-breeding ts in loss of vigour.*

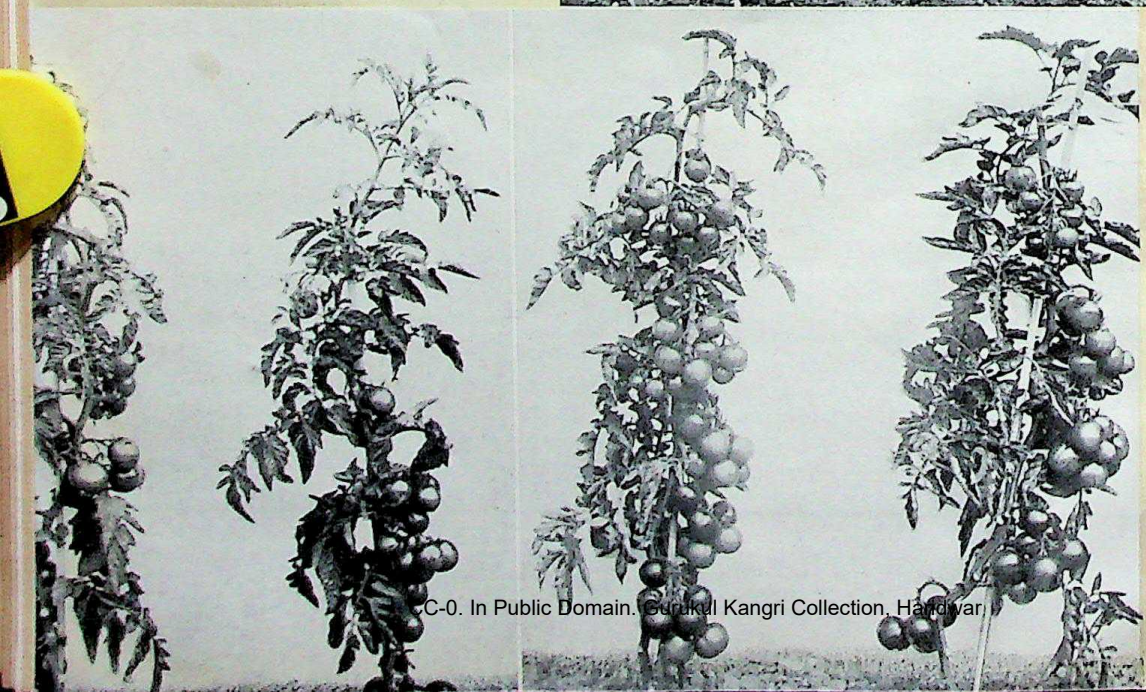


FIGURE 6 (*left*) – *[illegible] and cross-bred [illegible] (*Lycopersicum [illegible] lentum). *The cross-bred plants on the left are more vigorous than the in-bred plants on the right. The tomato shows [illegible] self-pollination, and [illegible] genetical structure is adapted to in-breeding; consequence, no [illegible] vigour follows continued in-breeding, as opposed to what happens in maize.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

RE 7 (*right*) – *A flowering shoot of the willow-herb* (Epilobium angu
w-herb is insect-pollinated, its flowers being coloured and striking. The anthers before the stigmata of the same flower mature. The chance of self-pollination is thus ially reduced. In the youngest flower (upper left), the anthers project forward and ust bursting to discharge their pollen. The style is directed downwards and the stigma ub-shaped and closed. The flower immediately below is older. Its anthers are ning to fall downwards, while the style has become more erect to occupy the position ed by the anthers. The stigma is just opening and exposing its inner receptive surfaces. two older flowers on the right show the exposure of the stigmatic surfaces and withering e anthers to a more pronounced degree. The youngest flower could not receive pollen on igma, but could dust pollen on to a bee. The older flowers could no longer place pollen e bee, but their stigmata could pick up such pollen as the bee is already carrying.

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 8 (*left*) – *Fixed and stained preparation pollen tubes growing in the style of* Oenothera organe (*preparation and photograph by Dr D. Lewis*). *Poll tion took place 45 minutes before the preparation was m Some pollen grains (deeply stained at the top of the ph graph) have germinated to give long tubes which ca seen growing well down the style at the bottom of the ph graph. Others, especially on the left, have produced short tubes. The former are 'compatible' grains whose t can achieve fertilization. The latter are 'incompatible' will never fertilize on egg nucleus. All pollen is inc patible on stigmata of the same flower. Pollen from o plants may be wholly incompatible, half compatible (a the illustration), or wholly compatible. Thus self-fer zation can never occur, while cross-fertilization can.*

URE 10 (*below*) – (*right*) *Pollen from thrum and* (*left*) *pin flowers of the heterostyled* s Primula obconica. *The former is larger and less variable than the latter. It was ht that heterostyly acted as a mechanical means of promoting cross-pollination, the ata of thrums touching those parts of a bee on which pin stamens had previously placed , and vice versa. Darwin, however, showed that this was not so, as he found that pollen the two types was different. Pin pollen will not grow down a pin style, nor thrum down a thrum style, even when such 'illegitimate' pollinations are deliberately made. physiological difference is often accompanied by a morphological difference as shown photograph.* (× 500.)

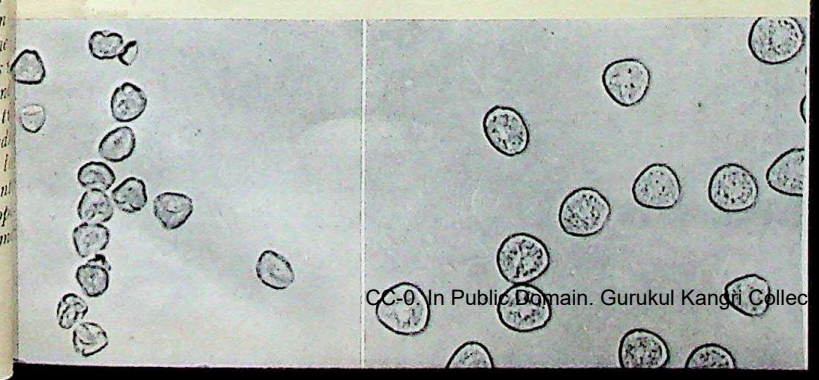
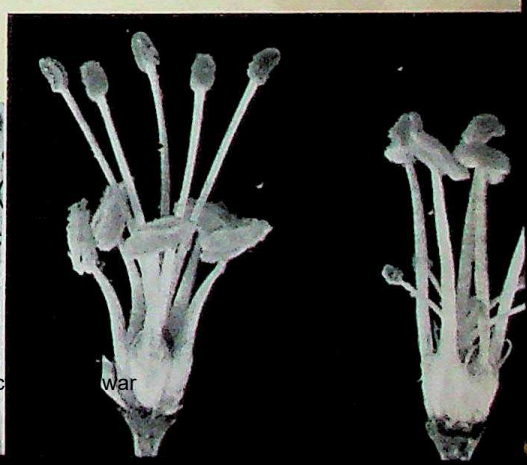


FIGURE 9 (*below*) – *Heterostyly in* Linum perenne. *petals and sepals have been removed for clarity. On left is a flower of the 'pin' type with long styles and s stamens. On the right is a flower of the 'thrum' type i short styles and long stamens. Note the pollen grains b released from the anthers and also present on the stigm Many plants, including primroses, show heterostyly.*



CC-0. In Public Domain. Gurukul Kangri Collec war

Digitized by Arya Samaj Foundation Chennai and eGangotri

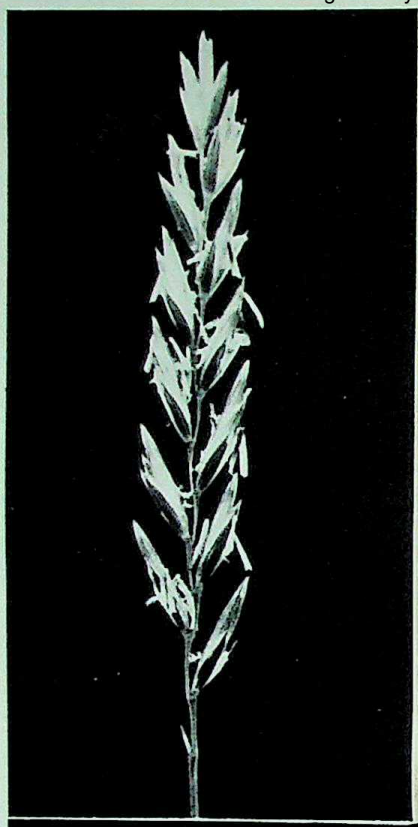
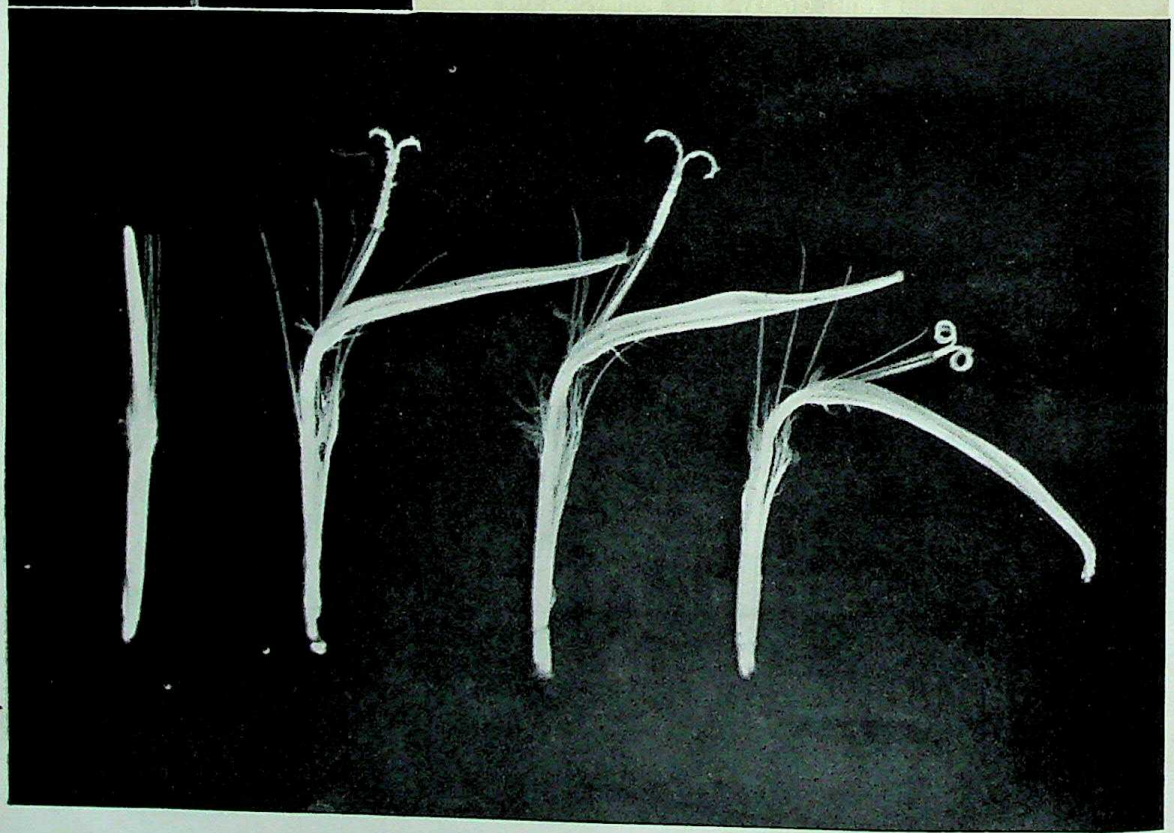


FIGURE 11 (*left*) – *A flowering spike of the couch grass* (Agropyrum repens). *Grasses are adapted to wind pollination. The anthers are extruded and swing in the wind, which then blows their pollen on to the feathery stigmata, also protruding from the flowers. These stigmata are most easily seen in the lower spikelets of the photograph. In spite of this mechanism, however, many grasses are regularly self-pollinated, for their anthers burst and pollinate the stigmata before either are extruded.*

FIGURE 12 (*below*) – *Single florets dissected from a flowering head of Scorzonera* (Scorzonera hispanica). *The youngest flower, on the left, has not yet opened. The next shows how the stigma pushes pollen out of the anther tube, visible just above the strap-shaped corolla. The pollen can be seen adhering to the outer, non-receptive, surface of the style and stigma. The stigma then opens out into two lobes, thereby exposing its inner, receptive, surfaces, much as in the willow-herb. These lobes curl over, as shown in remaining flowers, until the inner surfaces pick up pollen from the outer surface, so bringing about self-pollination. Most Compositae show similar behaviour. In spite of this, however, self-pollination is ineffective in some Compositae, e.g. the dahlia, for an incompatibility reaction, of the* Oenothera organensis *type, is operative. In the dandelion, on the other hand, pollination is not necessary for seed setting, reproduction being subsexual.*



CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

pollen fails to reach suitable stigmata. Success at the time of pollination, on the other hand, means that both the seed parent and the pollen parent will be well represented in the next generation, other things being equal. Thus control of pollination carries a great selective advantage, and, as a consequence, many adaptations to this end are found in flowering plants.

The first man to realize the part played by pollen in sexual reproduction seems to have been Sir Thomas Millington, one of the original Fellows of the Royal Society, in the seventeenth century. But the most remarkable feature of pollination was not appreciated until nearly a hundred years later. Pollination can presumably be accomplished most easily and economically by the transference of pollen from the anthers to the stigmata of the same flower. In such a case the flower need not even open and its generative parts would thus be less exposed to damage by the elements. This is, in fact, exactly what happens in the small inconspicuous cleistogamous flowers of the violet. Yet, in spite of these advantages, it was observed that in many species bees are continually engaged in transferring pollen from one flower to another, often on a different plant. Cross-pollination must clearly offer some great advantage over self-pollination to compensate for the extra hazards which it involves.

These hazards are reduced in many plants by special floral mechanisms, which also assist in mate discrimination. Darwin (1877) realized the importance of floral adaptations for his evolutionary theories and subjected some of them to experimental analysis, which fully verified their apparent function in reproduction.

Since flowering plants are non-motile, they must employ external agents for the dissemination of their pollen. Wind, water, birds, insects, and even, it is stated, snails all play their part with different plants, whose flowers show most remarkable adaptation to the use of the particular agent in question. Caution is, however, necessary in interpreting floral structures in terms of pollination adaptation, for many plants do not now rely on the method which their flowers suggest. Grasses, for example, are well adapted to cross-pollination by wind, yet many of them, including wheat, oats, and barley, are self-pollinated in most instances. The crossing mechanism is vitiated by the anthers bursting before they are extruded from the flower. Similarly many of the Compositae show a peculiar curling of the stigma lobes, in such a way that self-pollination is brought about. Yet all these plants have showy flower-heads of a kind usually associated with the attraction of insects for cross-pollination. Furthermore, in some Compositae, like the dahlia, pollen will not germinate on the stigmata of flowers of the same plant; and dandelions do not even require pollen for seed setting, in spite of their floral structures, their reproduction being subsexual.

These mixed control mechanisms must be regarded as relics of different stages in the evolution of the species (Mather 1942). Sometimes cross-breeding has been advantageous, but at others self-pollination has been more conducive to success. Since evolution is not reversible, each change has superimposed a new mechanism on the older ones, and we now observe the relics of these various steps in the history of the species.

Most plants are cross-pollinated, but some, like wheat and the tomato, regularly show self-pollination. Hence self-pollination is not of itself deleterious. In cross-breeding plants, as Darwin (1876) showed, self-pollination leads to few and weak offspring; but this is not true of the normally self-pollinating species. Their genetical structure is fitted to self-pollination. The breeding system is simultaneously determined by, and in control of, the genetical structure of the species. A change in one brings about a change in the other, and the breeding mechanism of a species can alter when conditions render it advantageous.

Self-pollination, by causing in-breeding, leads to high adaptation of individuals to the local environment. It reduces the frequency of variant, and hence less fit, individuals. But in-breeding also lowers the chance of prospective adaptive change because it leads to a less flexible genetical structure. Cross-breeding, on the other hand, gives great genetical flexibility though at the expense of a reduction in immediate adaptation and fitness (Mather, 1942). The breeding system of a species is the breeding system which, in its ancestors, most successfully balanced the discordant advantages of fitness and flexibility under the changing environments of the past. Thus the survival of a species, and indeed of its descendants, depends on the adequacy of its system of breeding, or, as we may call it, mating discrimination.

REFERENCES

DARWIN, C. *The Effects of Cross- and Self-fertilization in the Vegetable Kingdom*, London, Murray, 1876.

Idem. The Different Forms of Flowers on Plants of the Same Species, London, Murray, 1877.

MATHER, K. 'Polygenic Inheritance and Natural Selection,' *Biol. Rev.*, 1942 (in the press).

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The development and use of luminescent substances

LEONARD LEVY and DONALD W. WEST

Substances that shine in the dark have for centuries excited scientific no less than popular curiosity. During the last decade noteworthy advance has been made, not only in our theoretical knowledge of luminescent compounds but in their practical application. Dr Levy and Mr West, who have for many years specialized in the study of these interesting substances, describe the principal results and conclusions hitherto obtained.

Luminescent substances are materials capable of emitting light without the simultaneous emission of a sensible amount of heat. This definition includes types of luminescence which are not of any technical importance, such as self-luminous living organisms. It also includes chemi-luminescence, which is chemical action accompanied by the emission of light but by only slight emission of heat.

The most important class of luminescent substances, however, consists of materials capable of converting various types of invisible radiation into visible radiation. Many naturally occurring minerals display luminescent effects of this nature, but in practically no instance are they in any way comparable in performance with chemically prepared luminescent materials, now known as 'phosphors.' The term 'phosphor' is by convention restricted to artificially prepared materials displaying intense luminescent effects, in which the final stage of preparation is that of crystallization by heating to a high temperature with suitable fluxes.

Certain pure crystalline salts display intense luminescence without being heated, the most important of them being the platinocyanides and certain uranium salts. These are not, however, usually included in the term 'phosphor.'

Luminescence affords a very good example of a phenomenon which, until comparatively recently, was of scientific interest only, but which has now become of great practical importance. In fact, the application of certain phosphors will offer an important contribution to the amenities of peace-time civilization; and at the present time many are of great importance in connection with the war effort.

The first recorded example of a phosphor is the so-called 'Bologna phosphorus,' made in 1692 by a cobbler of Bologna, who prepared a crude form of barium sulphide by heating heavy spar to a high temperature, probably in the presence of some reducing agent. This substance glowed in the dark after exposure to light.

X-ray screens, first used in 1895, and the self-luminous mixture of zinc sulphide phosphor and radio-active matter (such as is used on watch dials) were almost the only practical applications of luminescence until recently. The really great development of luminescent materials has occurred during the last ten years, chiefly in connection with cathode-ray tubes for television and other purposes, and for fluorescent lighting.

Phosphors vary greatly in the character of their luminescence, and their individual properties determine their practical application. These characteristics are perhaps most easily appreciated after a study of figure 1, which shows (C–D) the relationship between the intensity of the luminescence and the time which has elapsed since the incident exciting radiation has ceased.

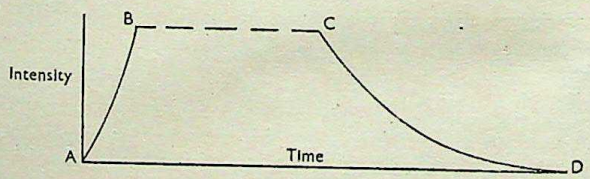


FIGURE 1

On excitation, there is a period of time, which may vary between a small fraction of a second and about half a minute (depending on the material and the intensity of the exciting radiation), during which the light emitted increases to a maximum. This is shown by the portion of the curve A–B. Saturation then occurs and the intensity of the emitted light remains constant until the exciting radiation ceases; this portion

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

of the curve is represented by B–C. In certain instances, as for example the action of alpha radiation on zinc sulphide phosphors, this portion of the curve is not horizontal, as the luminescent properties of the phosphor are progressively destroyed over a period of time. In many instances, however, it does remain horizontal. After the exciting radiation has ceased, the luminosity falls away according to the curve C–D. The luminosity may disappear in a small fraction of a second, or it may persist for many hours.

The emission of light during excitation, as represented by the portion of the curve B–C, is known as fluorescence; whereas the emission of light after incident radiation has ceased, represented by portion C–D, is known as phosphorescence. The latter obviously represents latent energy, stored in the phosphor, which is emitted more or less rapidly in the form of light. The intensity of the phosphorescence decays, and the time-intensity characteristics of the phosphorescence curve C–D are usually of great practical importance.

Phosphors show great variety in their response to different types of radiation. Some, as for example the zinc sulphide and zinc-cadmium phosphors, give excellent results when excited by almost every form of radiation except ultra-violet 2537 A, but other phosphors respond to one or two types of radiation only. The response of the more important types of phosphor to various types of radiation are shown in Table 1.

TABLE I

	Long ultra-violet 3650 A	Short ultra-violet 2537 A	X-rays	Cathode-rays	Alpha-rays from radio-active substances
Zinc and zinc-cadmium sulphides	Very good	Slight to fair	Very good	Very good	Very good
Cadmium and magnesium tungstates	Almost nil	Very good	Good	Good	Very slight or nil
Zinc and zinc-beryllium silicates	Very slight	Very good	Fair	Very good	Very slight or nil
Cadmium borate	Poor	Very good	Very slight	Moderate	Very slight or nil
Cadmium and zinc phosphates	Poor	Very good	Very slight	Good	Very slight or nil

The luminescence can be varied by suitably modifying the method of manufacture of the phosphor; for example, cadmium tungstate, which displays a good bluish fluorescence under X-rays, is quite unaffected by long-wave ultra-violet. If, however, a small quantity of uranium is added the resulting phosphor displays pink fluorescence under X-rays and a vivid red fluorescence of great intensity under long-wave ultra-violet.

Experience has shown that in order to produce phosphors of the highest possible efficiency, certain procedures must be rigidly adhered to. The phosphor must be prepared, by precipitation or otherwise, in an absolutely pure condition. Metals such as iron, vanadium, and cobalt must be completely absent—their presence, even in the most minute traces, exerts a very prejudicial effect. The production of phosphors is more akin to bacteriological than to chemical work in this respect. Generally speaking, certain additives must be included in the phosphor to enhance the luminescent phenomena. The amount of additive required is often quite small, of the order of 1 part in 20,000. In other types of phosphor the amount is comparatively large, say 0·25–5 per cent. The additives are usually known as activators. The phosphor precipitate, together with its activator, is mixed with certain fluxes, which are varied according to the purpose for which the phosphor is intended, and the mixture is then heated to a high temperature, to cause the phosphor to crystallize. In some cases (e.g. calcium tungstate) the phosphor precipitate may be sufficiently crystalline to display some luminescent properties itself. The intensity of this luminescence is, however, very much lower than it is after heating.

Phosphors can be divided into three classes:

(1) The type exemplified by zinc and zinc-cadmium sulphides, in which the activator is present in minute quantities, usually not more than 1 part in 10,000.

(2) The type exemplified by zinc and zinc-beryllium silicates, in which the activator (manganese) required to produce luminescence is present in relatively large quantities, of the order of 0·5 per cent.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

(3) Phosphors which are apparently absolutely pure salts and do not require the presence of any activator. This type is exemplified by the tungstates of magnesium, cadmium, and calcium. Even in this class, however, the colour of the luminescence can be modified by small additions. For example, calcium tungstate exhibits a blue fluorescence, but the addition of about 1 per cent. of samarium changes the colour to pink.

It has already been mentioned that the portion of the curve in figure 1, C–D, representing phosphorescence, is often of great importance. In certain instances it is necessary that zinc and zinc-cadmium sulphide phosphors should exhibit fluorescence without any phosphorescence, and it has been found that the presence of a small trace of nickel, of the order of 1 part in 1,000,000 or even less, reduces the phosphorescence to an extremely low level without materially affecting the fluorescence. This is a most remarkable fact and appears to be a unique characteristic of the metal nickel.

The spectra of phosphors are generally continuous bands of radiation extending sometimes into the ultra-violet and infra-red regions of the spectrum. Sometimes, as in calcium tungstate activated with samarium, a certain amount of fine structure is present also. The band sometimes extends over the whole visible spectrum with one or two well-defined peaks. In other cases the bands are relatively narrow and the resulting colour is much more saturated. Examples of fluorescence spectra are shown in figure 2.

Intensities of luminescence vary very greatly,

TABLE 2

Phosphor	Excitation	Intensity
ZnCdS(Ag)	X-rays, 6 ma. 90 kv.	5 equivalent foot-candles
ZnS(Ag) plus ZnCdS(Cu)	Cathode-ray scanning spot in television tube	About 6,000,000 equivalent foot-candles
ZnS(Cu)	α-rays (70 micrograms per gram)	0·04–0·05 equivalent foot-candles
ZnS(Cu)	Ultra-violet, 125 watts at 3 ft.	6 equivalent foot-candles
SrS(Bi)	Daylight	1·5 equivalent foot-candles

from small luminosities as in the case of radio-active luminous compound of low quality as used for watch dials, etc., to luminosities of enormous intensities as exhibited by the scanning spot in television tubes. Table 2 shows the approximate values of certain fluorescence intensities.

Fluorescence is explained in terms of modern atomic physics in the following manner. The electron is supposed to be raised from a lower or filled band in the lattice to the conduction band by the absorption of radiation. The activator supplies electrons to replace those excited from the lower band. Emission of light takes place when the electron falls from the conduction band to the impurity band.

Phosphorescence is explained by postulating the presence of metastable bands (the so-called 'trapping-levels') close to the conduction band. The electrons in the trapping-levels can be released only via the conduction band, owing to thermal oscillations.

The first really practical use for luminescent substances was for X-ray diagnosis. Screens coated with luminescent materials were used for converting X-rays into visible radiation, thus enabling visual examinations to be carried out. A different type of screen is also used for converting X-radiation into actinic radiation, thus very greatly reducing the exposure necessary when making a radiograph. Phosphors for X-ray work should be free from phosphorescence, as otherwise a blurred image of moving organs will be seen. It was this which prevented the use of zinc sulphide for X-ray work for many years. Zinc and zinc-cadmium sulphide phosphors give far more intense fluorescence under X-rays than other substances, but always exhibit phosphorescence, which rendered them quite unsuitable. The discovery of the 'nickel killer,' already referred to, removed this difficulty.

Radio-active luminous compound has been known for quite a long time. It has been in general use for clock and watch dials, but a very much higher grade is now used for luminizing the dials of aeroplane instruments, ships' compasses, and other purposes. It is a curious fact that only one phosphor is used for this purpose, zinc sulphide activated with copper. It responds to alpha-radiation, which constitutes nearly all the energy of radio-active radiations.

Zinc and zinc-cadmium sulphide phosphors are employed in conjunction with long-wave ultra-violet radiation for display purposes for advertising and stage effects, and they have also

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

found considerable application since the war for blackout illumination. They afford a simple and easy method of obtaining low levels of illumination without the use of electrical fittings and supplies.

Sulphides, silicates and tungstates and certain other phosphors all find application for use in cathode-ray tubes for various purposes. The great and rapid development in the use of cathode-ray tubes has led to a concomitant increase in the number and variety of the phosphors required to produce certain special effects. The screen in cathode-ray tubes used for instruments such as oscillographs and the like is usually made of zinc silicate giving a green fluorescence. The screen in television cathode-ray tubes is required to give an image which is substantially black and white. This is not well achieved by any single phosphor, which, even if its spectrum is continuous, always shows a predominance in certain portions. Very good results are obtained by mixing together zinc-cadmium sulphide, giving orange and orange-yellow fluorescence, with zinc sulphide giving a blue fluorescence which extends back into the green portion of the spectrum. The fluorescence spectrum of a mixture of these two phosphors is shown in figure 2, and it will be seen that they are roughly complementary, the two together making up practically the whole of the visible spectrum. Cathode-ray tubes with special phosphors have found a great many new applications during the present war, for example in radiolocation and in new methods of gun-laying.

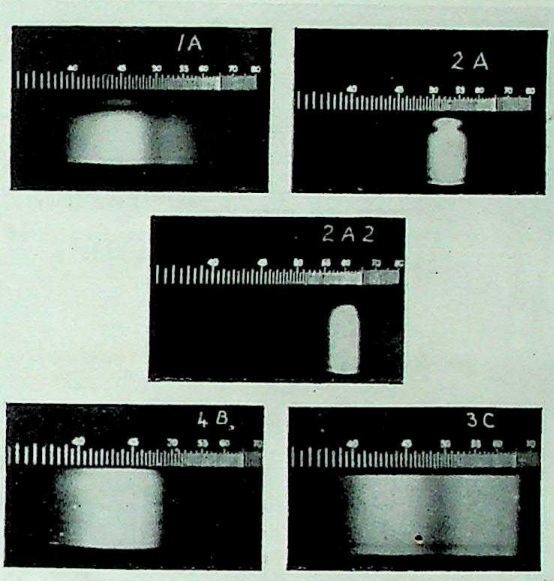


FIGURE 2 – *1A, cadmium tungstate; 2A, zinc silicate; 2A2, zinc phosphate; 4B, zinc sulphide (Ag); 3C, zinc sulphide and zinc-cadmium sulphide mixture.*

Phosphors are principally used for the fluorescence which they exhibit. In certain cases, however, it is the phosphorescent and not the fluorescent effects which are desired. Thus strontium sulphide phosphors have found such use in the present war for black-out signs of various kinds. Unfortunately the alkaline earth phosphors are chemically unstable and require the use of special media to prevent their decomposition. In the past these phosphors have been employed in media which were totally unsuitable, with the result that their luminescent qualities speedily deteriorated.

A second type of phosphorescent phosphor is zinc sulphide activated with copper. This exhibits a very intense phosphorescence which, however, dies away far more rapidly than that of the alkaline earth phosphors. The intensity curves of the two types of phosphors cross in a few minutes, after which the phosphorescence of the strontium sulphide is always higher than that of the zinc sulphide. Zinc sulphide phosphors are, generally speaking, very stable. They require suitable media to prevent photolysis, but are not readily decomposed chemically. They can in fact be incorporated in suitable frits to yield phosphorescent enamels. These enamels are very useful in cases of complete failure of the electric lighting, as they afford sufficient light to enable objects to be discerned in an otherwise unlighted room. Black-out conditions are of course particularly favourable for the use of phosphorescent phosphors, which can be incorporated in the synthetic resins employed for switch covers, door handles, etc. In order to make such articles of widespread utility it would be necessary to effect further improvements in the phosphorescence.

By far the largest and most important application of luminescent powders is undoubtedly in illumination. The first discharge tubes to utilize luminescent powders were the familiar high voltage neon and mercury-filled tubes used for advertising, but similar tubes were also extensively developed in this country for general lighting purposes. The technique used for the high voltage fluorescent tubes has more recently been widely applied to similar tubes operating directly from ordinary supply voltages, and these mains-voltage fluorescent tubes bid fair to revolutionize artificial light sources.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

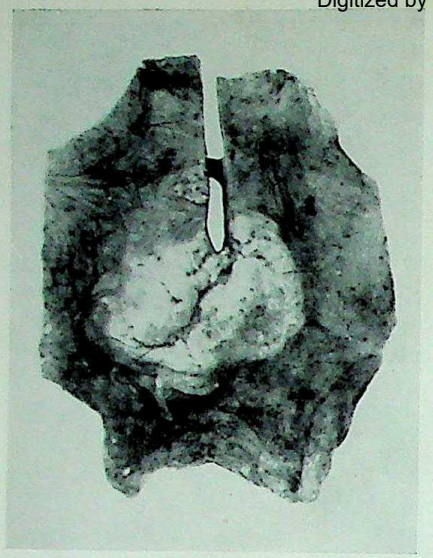


FIGURE 1 – *Mule-spinners' cancer: the primary lesion.*

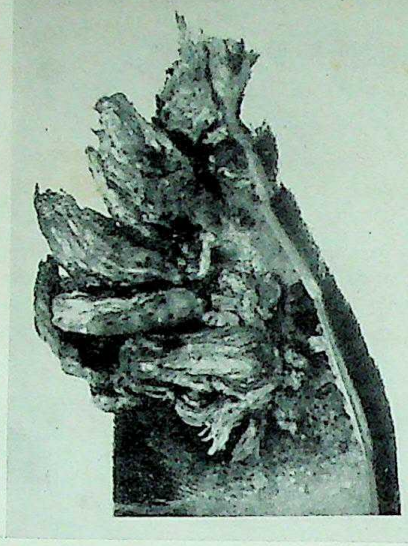


FIGURE 2 – *Papillomatosis of rabbit's ear, induced by the repeated application of a tar prepared from acetylene (Kennaway).*

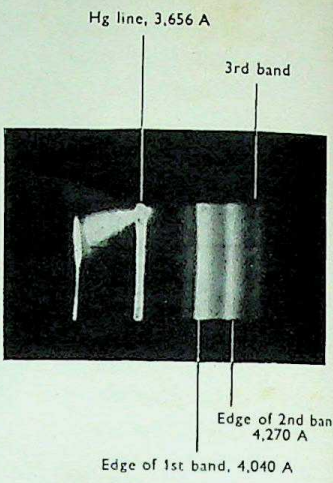


FIGURE 3 – *Fluorescence spectrum of* 3 : 4*-benzpyrene (Hieger). Note sharply defined edges of the two main fluted bands.*

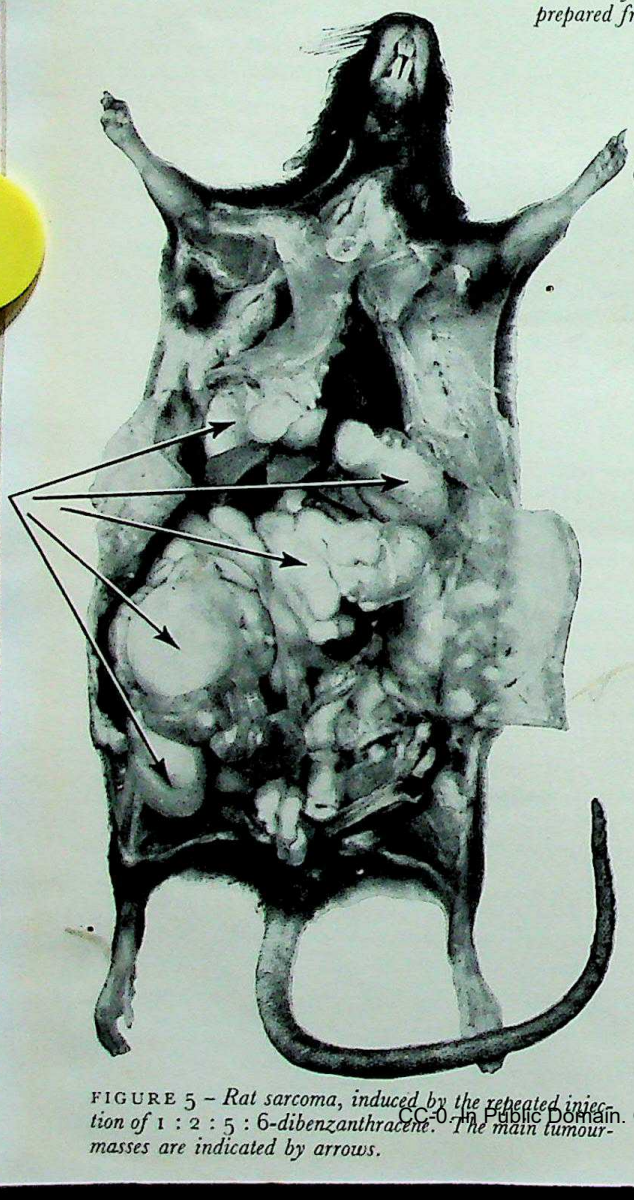


FIGURE 5 – *Rat sarcoma, induced by the repeated injection of* 1 : 2 : 5 : 6*-dibenzanthracene. The main tumour-masses are indicated by arrows.*

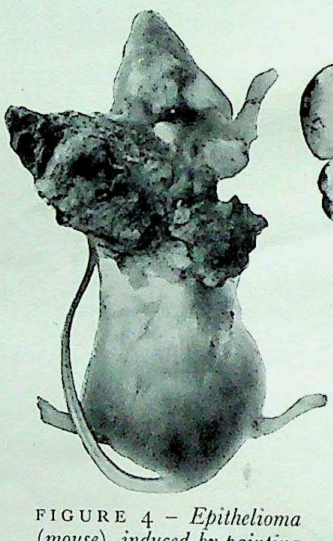


FIGURE 4 – *Epithelioma (mouse), induced by painting the skin with a benzene solution of* 3 : 4*-benzpyrene.*

FIGURE 6 – *Invasion of the liver by a malignant connective-tissue tumour (fowl), induced with* 1 : 2 : 5 : 6*-dibenzanthracene.*

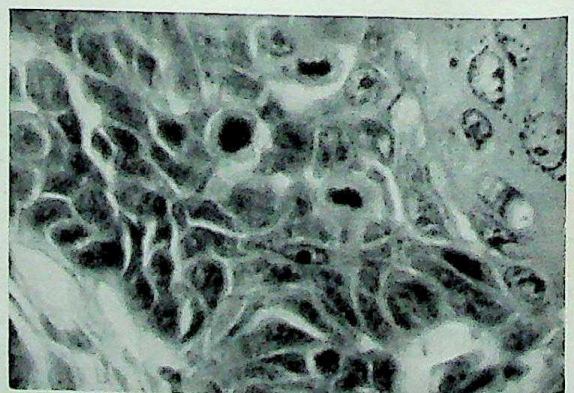


FIGURE 7 – *Dividing malignant cells from a tumour (of mouse skin) induced with* 10*-hydroxymethyl-*1 : 2*-benzanthracene.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Vidya Sanai Foundation Chennai and eGangotri

The production of cancer by chemical compounds

ALEXANDER HADDOW

Until comparatively recent times the cure of disease was a matter of trial and error, but the rapid development of science has revolutionized experimental medicine. Dr Haddow's article describes the application of chemical knowledge to the investigation of cancer, and affords a striking example of one aspect of the new technique.

The history of carcinogenesis illustrates, with a wealth of examples, the dependence of accident and planned experiment.

The tale began when Percivall Pott described a particular form of cancer occurring in chimney-sweeps (cancer scroti, in *Chirurgical Observations*, 1775) and traced it to a specific cause, namely contamination of the skin by soot. Other cases were reported by a long line of English surgeons, including Earle, Astley Cooper, Hughes Bennett, Paget, and Butlin. In the latter part of the nineteenth century appeared three new and powerful stimuli to investigation, in fresh accounts of cancer as an industrial hazard. Thus in 1875 von Volkmann discovered occupational skin tumours among the workers in the tar industry at Halle. In the following year the celebrated Joseph Bell of Edinburgh described the earliest cases of 'paraffin cancer' in the Scottish shalefield. In 1887 was found the first example of skin cancer affecting operatives in the Lancashire cotton-spinning industry and attributable to contact with lubricating oil ('mule-spinners' cancer') (*see* figure 1).

All these were the results of undesigned 'natural' experiments. Answers to the questions they posed could be found only by systematic inquiry, and the first essential lay in the reproduction of the disease at will. One of the earliest attempts was made by Hanau in 1889. Inspired by von Volkmann's paper, he tried to induce cancer in rats and dogs by painting the skin 'mit Hallenser Braunkohlentheer,' but without result. Success proved tardy, just eluded Bayon in this country (1912), but was finally vouchsafed to Yamagiwa and Ichikawa (1915), who produced undoubted cancers by application of coal-tar to the ears of rabbits. In 1918 Tsutsui (a pupil of Yamagiwa) showed the advantage of painting the skin in *mice* as a method of testing—a simple technical variation but one which influenced all later developments most profoundly.

The scene was now set for a wider attack to elucidate the nature of the cancer-producing agent, and the instrument had already been described by the renowned Lebert (1851), in prophetic advocacy of a chemical approach: '*Il faut que, pour un pareil travail, un homme profondément versé dans la connaissance anatomique et pathologique du cancer se réunisse à un chimiste qui, de son côté, soit au courant des progrès les plus récents de la science.*'

The first-fruits of this union came in 1921–26, with a demonstration by Bloch in Zürich that the active substance of coal-tar was concentrated in the higher boiling fractions as a neutral compound, free from nitrogen, arsenic, or sulphur, capable of forming a stable complex with picric acid, and probably belonging to the class of cyclic hydrocarbons.

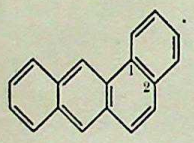
In 1924–25 Kennaway succeeded in producing carcinogenic tars by the pyrolysis of petroleum, skin, hair, yeast and cholesterol, and by leading acetylene and isoprene with hydrogen through strongly heated tubes. The tars obtained at successively higher temperatures (450–1,250° C.) showed an ascending order of potency; and these results could be explained by assuming that acetylene was a common decomposition product, and that the carcinogenic material was actually formed from acetylene (*see* figure 2). There gradually emerged the strong general conclusion that the carcinogenic agent was a complex hydrocarbon of aromatic type.

Since the carcinogenic tars usually showed strong fluorescent properties, Mayneord (1927) examined their fluorescence spectra and discovered them to possess a characteristic spectrum consisting of three bands at low dispersions. This

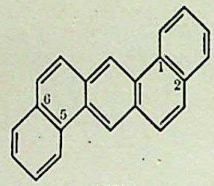
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

vital clue was developed by Hieger in an investigation of a number of polycyclic aromatic hydrocarbons, particularly those related to anthracene. 1 : 2-*Benzanthracene* (I) was found to give a spectrum similar to that of the carcinogenic mixtures, and it was this which led Cook to embark on the long series of studies of benzanthracene homologues which founded our knowledge of the structural conditions underlying carcinogenic action. About this time Clar had just published methods for the synthesis of certain benzanthracene hydrocarbons. These compounds were tested for carcinogenic activity by Kennaway and Hieger (1930), who soon obtained positive results with 1 : 2 : 5 : 6-dibenzanthracene (II); this was, therefore, the first known compound manifesting pronounced carcinogenic properties (figures 5 and 6).

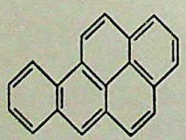


(I)
1 : 2-*Benzanthracene*



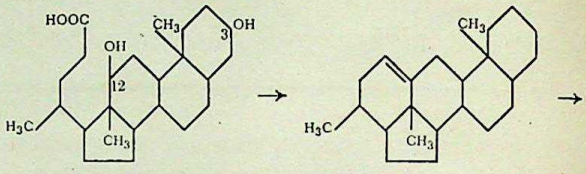
(II)
1 : 2 : 5 : 6-*Dibenzanthracene*

The fluorescence spectrum—in Kennaway's words 'the single thread that led all through this labyrinth'—was also used by Hieger in the concentration of the agent from coal-tar pitch, culminating in the isolation of a hydrocarbon which showed the characteristic spectrum (figure 3), and which proved to be strongly carcinogenic (1933) (*see* figure 4). Its properties suggested one of the two benzpyrenes, and these were synthesized by Cook and Hewett, who were soon able to prove the identity of one of the compounds (3 : 4-benzpyrene, III) and the substance from pitch.



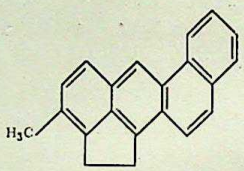
(III)
3 : 4-*Benzpyrene*

Thus far the clues drawn from industrial cancer had led to the identification of the substance responsible, and to the discovery of other hydrocarbons related to benzanthracene and possessing carcinogenic properties. The possibility that such compounds might play a part in the causation of 'spontaneous' cancer was opened up by recognition, following the advances in sterol formulation due to Rosenheim and King in 1932, that many naturally occurring compounds have somewhat similar condensed polycyclic systems. Thus dehydronorcholene (V), a hydrocarbon prepared by Wieland and Schlichting from the bile-acid deoxycholic acid (IV), is a hydrogenated derivative of 1 : 2-benzanthracene, and in 1933 both Wieland and Dane, and Cook and Haslewood, obtained from it, by dehydrogenation with selenium, the fully aromatic hydrocarbon methylcholanthrene (VI).



(IV)
Deoxycholic acid

(V)
Dehydronorcholene



(VI)
2-*o*-*Methylcholanthrene*

This compound soon proved to have carcinogenic potency of a high order—as Cook had indeed predicted. The structure was rapidly established and confirmation provided by its synthesis (Fieser and Seligman).

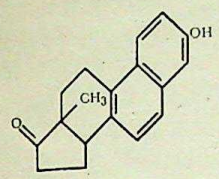
There is as yet no proof that changes of the kind envisaged take place *in vivo*. Both cholic acid and deoxycholic acid have a hydroxyl group in such a position (12) as would promote the necessary cyclization of the side-chain. On the other hand, Rossner (1937) obtained methylcholanthrene by dehydrogenation of complex hydrocarbazole derivatives formed by the interaction of cholestenone or cholestanone with phenylhydrazine. In none of these cases is there any special circumstance to favour ring-closure, and hence Cook regarded this result as suggestive of an inherent tendency for the sterol molecule to pass into a methylcholanthrene derivative.

However, marked carcinogenicity is not generally found in compounds possessing hydrogenated rings, so that a further stage of dehydrogenation would be required. Important here is a finding by Ghiron (confirmed by Kennaway) that injection of deoxycholic acid itself may produce connective-tissue tumours in mice; in this case it will be particularly desirable to find whether deoxycholic acid is intrinsically active, or is subject to a transformation, yielding traces of an active

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

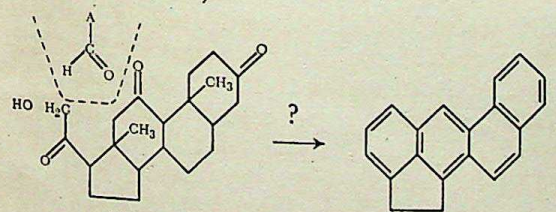
Digitized by Arya Samaj Foundation Chennai and eGangotri

product. One of the best analogies for aromatization of the hydrogenated ring system is provided by the oestrus-producing hormone equilenin (VII), possessing two aromatic rings and probably arising from a non-aromatic steroid precursor (Girard, Fieser).



(VII)
Equilenin

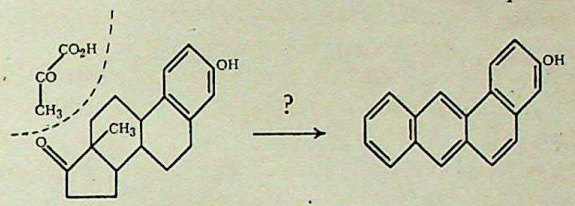
Fieser has recently reviewed newer opinions on the relationships between the steroids, dealing with Robinson's suggestion of a scheme involving the biosynthesis of steroids from tyrosine, and with the hypothesis of Reichstein, according to which the synthetic units may be three-carbon sugars. In the latter process, condensation of seven units would afford the cortical steroids (C_{21}) and could proceed further to give the bile-acids (C_{24}) and cholesterol (C_{27}), the C_{19} androgens and C_{18} oestrogens being assumed to arise by metabolic degradations of C_{21} steroids. In Fieser's view the rough analogy between equilenin and methylcholanthrene suggests that, if the latter does arise by a process of abnormal metabolism, this process would be associated with the normal one which results in the production of oestrogenic hormones. He therefore invites consideration of the production of carcinogens from the principles of the adrenal cortex, visualizing such reactions as might ensue from the condensation of dehydrocorticosterone (VIII) with formaldehyde (to give cholanthrene, IX).



(VIII)
Dehydrocorticosterone
(plus an aldehyde)

(IX)
Cholanthrene

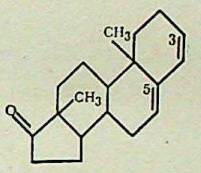
He also suggests another route to a cholanthrene in the condensation of oestrone (X) or equilenin with pyruvic acid, followed by aromatization, ring-closure to give the terminal benzenoid nucleus, and further dehydrogenation. A difficulty arises here (as also for deoxycholic acid, above), since the product, on account of the persistence of the hydroxyl group at C_3 characteristic of partially aromatic steroid hormones, would be a 3-hydroxy derivative (XI) and unlikely to be carcinogenic. A highly relevant observation was, however, made by Burrows, Cook, Roe, and Warren when they isolated from the urine of a male with an adrenal tumour a substance (XII) lacking this characteristic 3-hydroxyl group, and so showing that the C_3-hydroxyl may in certain circumstances be eliminated while the ring-system is still non-aromatic. The same compound



(X)
Oestrone
(plus pyruvic acid)

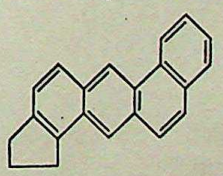
(XI)
3-Hydroxycholanthrene

was later isolated by Wolfe, in Fieser's laboratory, from the urine of a female with adrenal tumour.

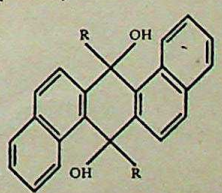


(XII)
$\Delta^{3,5}$-Androstadiene-17-one

Mention may here be made of a discovery by Lacassagne in 1932, that injection of the female sex hormone produces, in favourable conditions, cancer of the breast in male mice—the first experiment in which cancer was produced by a naturally occurring compound. About the same time Cook and Dodds showed that individual synthetic compounds, e.g. 5 : 6-*cyclo*penteno-1 : 2-benzanthracene (XIII) and 3 : 4-benzpyrene (III), might show oestrogenic as well as carcinogenic activity; and oestrogenic action was also discovered in certain di-alkyl derivatives of 1 : 2 : 5 : 6-dibenz--9 : 10-dihydroanthraquinol (XIV).



(XIII)
5 : 6-cyclo-*Penteno-*
1 : 2-*benzanthracene*



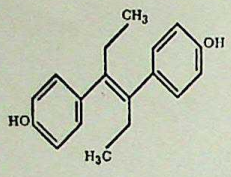
(XIV)
Di-alkyl-dibenzanthracene djols

This soon led to larger scale researches by Dodds and Robinson and to the synthesis of artificial oestrogens of extraordinary potency.

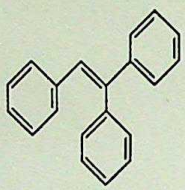
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

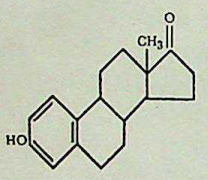
Among such compounds discovered later, diethylstilboestrol (XV) and triphenylethylene (Schönberg) (XVI) are now known to be capable of inducing breast and testis tumours in mice of susceptible strains. The former compound presents a rough resemblance to oestrone (XVII) and to chrysene (XVIII), and triphenylethylene may also be formulated as a phenanthrene derivative with one ring disrupted, or possibly as a benzanthracene system with two rings disrupted.



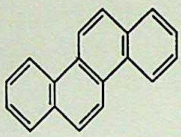
(XV)
Diethylstilboestrol



(XVI)
Triphenylethylene

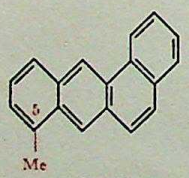


(XVII)
Oestrone

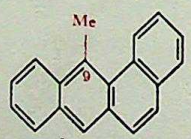


(XVIII)
Chrysene

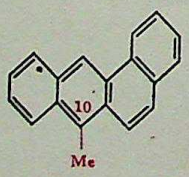
There has now accumulated a mass of data on the basis of which it is possible to relate molecular features and biological activity, and to illustrate a community of structure for the majority of carcinogenic compounds. Cook's study of the benzanthracene homologues first disclosed the great significance of position 5: whereas the parent hydrocarbon is only weakly active, methyl substitution at position 5 confers a high order of potency (XIX). It was later shown that substitution at positions 9 or 10 (XX, XXI) also leads to highly carcinogenic compounds, and indeed 10-methyl-1 : 2-benzanthracene is the most active of all the monomethyl derivatives of the parent compound. Of the remaining monomethyl isomerides, only the 6-methyl derivative exhibits notable activity, the others little or none.



(XIX)
5-*Methyl*-1 : 2-*benzanthracene*

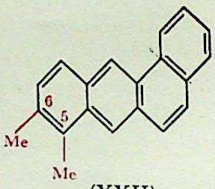


(XX)
9-*Methyl*-1 : 2-*benzanthracene*

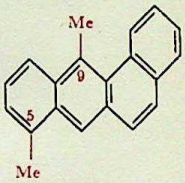


(XXI)
10-*Methyl*-1 : 2-*benzanthracene*

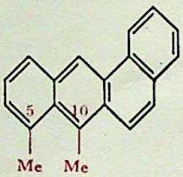
Proceeding to dimethyl-benzanthracenes, substituents at any two favourable positions reinforce each other, so that the activity of the new compound is enhanced. Thus 5 : 6-dimethyl-1 : 2-benzanthracene (XXII) is more active than the compound possessing only one methyl group at position 5 or 6, high activity is shown by 5 : 9- and 5 : 10-dimethyl-1 : 2-benzanthracene (Fieser) (XXIII, XXIV), and extreme potency is reached in 9 : 10-dimethyl-1 : 2-benzanthracene (Bachmann, Kennaway) (XXV).



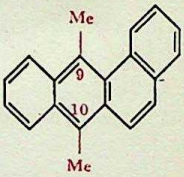
(XXII)
5 : 6-*Dimethyl*-1 : 2-*benzanthracene*



(XXIII)
5 : 9-*Dimethyl*-1 : 2-*benzanthracene*

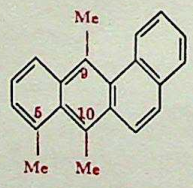


(XXIV)
5 : 10-*Dimethyl*-1 : 2-*benzanthracene*

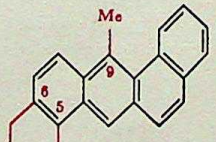


(XXV)
9 : 10-*Dimethyl*-1 : 2-*benzanthracene*

Still greater augmentation is effected by substitution simultaneously in *three* favourable positions, as in 5 : 9 : 10-trimethyl-1 : 2-benzanthracene (XXVI) and 9-methyl-1 : 2 : 5 : 6-dibenzanthracene (XXVII).



(XXVI)
5 : 9 : 10-*Trimethyl*-1 : 2-*benzanthracene*



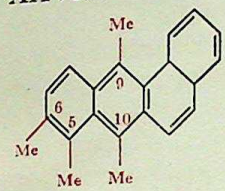
(XXVII)
9-*Methyl*-1 : 2 : 5 : 6-*dibenzanthracene*

But there is a limit to advance in potency by increase in substituted positions, since the compounds in which the four most favourable are

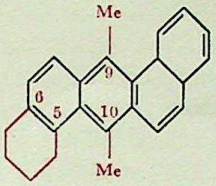
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

substituted [5 : 6 : 9 : 10-tetramethyl-1 : 2-benzanthracene (XXVIII) and 9 : 10-dimethyl-1 : 2 : 5 : 6-dibenzanthracene (XXIX)] show *decreased* activity as compared with XXVI and XXVII:

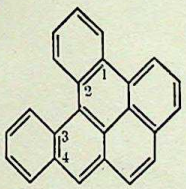


(XXVIII)
5 : 6 : 9 : 10-*Tetramethyl*-1 : 2-*benzanthracene*

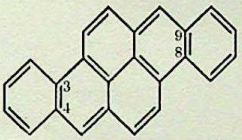


(XXIX)
9 : 10-*Dimethyl*-1 : 2 : 5 : 6-*dibenzanthracene*

This at once suggests the dependence of activity on optimal complexity, a conclusion which Cook had stressed at an early stage in these investigations, and which is upheld by many later examples. The limits of complexity compatible with activity are represented by two hexacyclic hydrocarbons, 1 : 2 : 3 : 4- and 3 : 4 : 8 : 9-dibenzpyrene (XXX, XXXI):

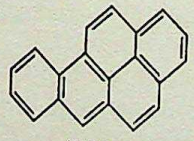


(XXX)
1 : 2 : 3 : 4-*Dibenzpyrene*

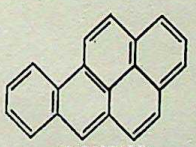


(XXXI)
3 : 4 : 8 : 9-*Dibenzpyrene*

These cases permit some degree of analogy with derivatives of 3 : 4-benzphenanthrene and chrysene, and remind us that while Cook regarded 3 : 4-benzpyrene as most nearly related to 1 : 2-benzanthracene (as in XXXII), for other reasons Fieser suggested it should more suitably be formulated as a chrysene derivative (as XXXIII):

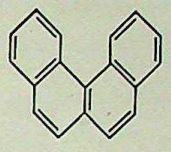


(XXXII)

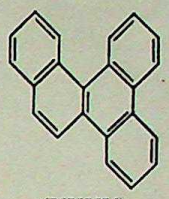


(XXXIII)

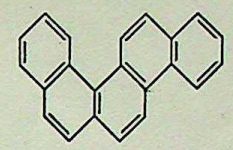
Marked progress was achieved on complete examination of the six hydrocarbons consisting of four condensed aromatic rings, and of the fifteen compounds having five such rings. This revealed activity in 3 : 4-benzphenanthrene (XXXIV) and 1 : 2 : 3 : 4- and 1 : 2 : 5 : 6-dibenzphenanthrene (XXXV, XXXVI), and it also transpired that *chrysene*, as well as 1 : 2-*benzanthracene* and 3 : 4-*benzphenanthrene*, must be regarded as a parent compound of carcinogenic derivatives. Each of these hydrocarbons is a derivative of phenanthrene, substituted in two of the 1-, 2-, 3- and 4-



(XXXIV))
3 : 4-*Benzphenanthrene*

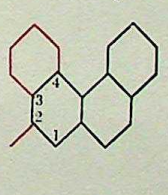


(XXXV)
1 : 2 : 3 : 4-*Dibenzphenanthrene*

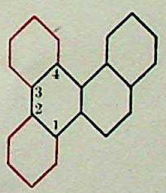


(XXXVI)
1 : 2 : 5 : 6-*Dibenzphenanthrene*

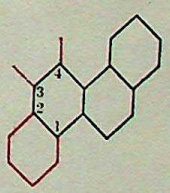
positions. Further substitution in the remaining positions gives rise to highly carcinogenic hydrocarbons (e.g. 2-methyl-3 : 4-benzphenanthrene (A), 1 : 2 : 3 : 4-dibenzphenanthrene (B), 1 : 2-dimethylchrysene (C), 3 : 4-benzpyrene (D), 9 : 10-dimethyl-1 : 2-benzanthracene (E). Moreover, substitution is effective whether by two benzene rings or by one benzene ring and one or two methyl groups: this finally led Hewett and Martin to the synthesis of 1 : 2 : 3 : 4-tetramethylphenanthrene (F)—a key compound which links the active derivatives of 1 : 2-benzanthracene, 3 : 4-benzphenanthrene and chrysene, may be regarded as the *prototype* of all these compounds, and has only recently itself proved carcinogenic.



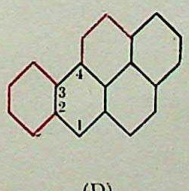
(A)



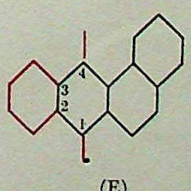
(B)



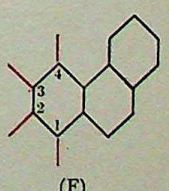
(C)



(D)



(E)



(F)

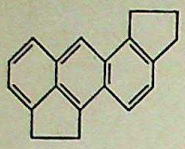
(Numbering indicates relation to phenanthrene)

Even the phenanthrene nucleus is not indispensable, since activity is marked in structures

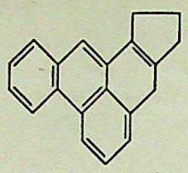
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

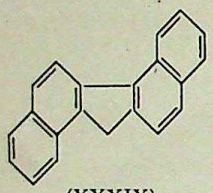
XXXVII and XXXVIII and in certain dibenzfluorenes (e.g. XXXIX), and is detectable in as simple a compound as 9 : 10-dimethylanthracene (XL) (Warren).



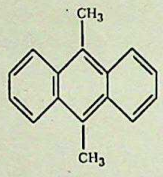
(XXXVII)
5 : 10-*Dimethylene*-1 : 2-cyclopentenoanthracene



(XXXVIII)
Δ^3-*Dehydro*-3 : 4-trimethylene-isobenzanthrene-2

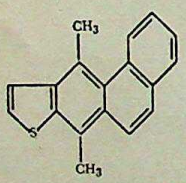


(XXXIX)
1 : 2 : 5 : 6-*Dibenzfluorene*

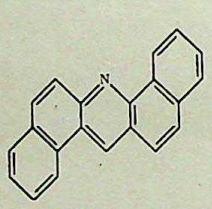


(XL)
9 : 10-*Dimethylanthracene*

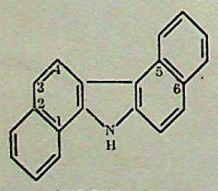
Nor is activity restricted to hydrocarbons, for it is found in a sulphur-containing compound (XLI) (Sandin and Fieser), and in such nitrogenous analogues as dibenzacridines and dibenzcarbazoles (e.g. XLII, XLIII). Boyland directed attention to 3 : 4 : 5 : 6-dibenzcarbazole, on account of its possible formation from β-naphthylamine, one of the intermediates thought to be responsible for cancer of the bladder in dye-workers, and now known, from experiments on dogs, to be able to induce this disease experimentally (Hueper, Bonser).



(XLI)
4 : 9-*Dimethyl*-5 : 6-*benzthiophanthrene*



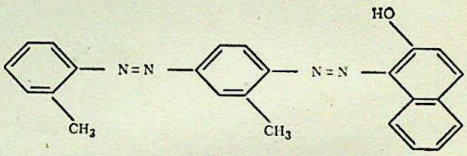
(XLII)
1 : 2 : 5 : 6-*Dibenzacridine*



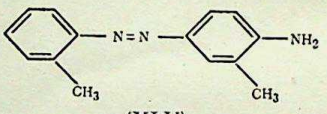
(XLIII)
1 : 2 : 5 : 6-*Dibenzcarbazole*

The substituent is also capable of variations compatible with activity, as in many compounds with oxygen-, nitrogen-, and halogen-containing groups, mostly at positions 10, 9, and 5 in 1 : 2-benzanthracene.

Carcinogenic potency is by no means confined to polycyclic compounds. Exceptional cases are provided by two styryl quinoline trypanocidal drugs (Browning) and by radio-active elements and their salts. But the great majority of those remaining fall in the class of *azo compounds*. As early as 1906 B. Fischer described epithelial proliferation following the injection of scarlet red (XLIV). Although the growths were non-malignant, Fischer rightly claimed his discovery as the first case of the induction of tumour-like proliferation by a chemical compound. A few years later, Hayward found that the active part of the scarlet red molecule was represented by 4′-amino-2 : 3′-azotoluene (XLV), and experiments with this and related compounds continued to be reported for a number of years.



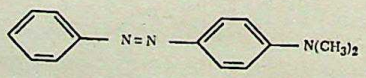
(XLIV)
'*Scarlet red*'



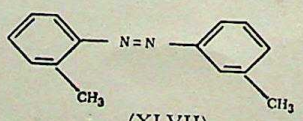
(XLV)
4′-*Amino*-2 : 3′-*azotoluene*

But little progress was made before a large-scale development by Yoshida (1931) when 4′-amino-2 : 3′-azotoluene was observed to produce proliferation of liver tissue in mice and liver tumours in rats.

Kinosita later examined other derivatives of azobenzene, and found an isomer of aminoazotoluene [*p*-dimethylaminoazobenzene (XLVI)] to be highly active in producing liver tumours. This substance, with 4′-amino-2 : 3′-azotoluene and 2 : 3′-azotoluene (XLVII), is also capable of



(XLVI)
p-*Dimethylaminoazobenzene*



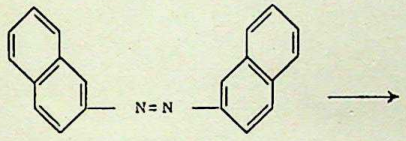
(XLVII)
2 : 3′-*Azotoluene*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

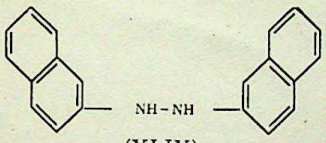
Digitized by Arya Samaj Foundation Chennai and eGangotri

producing connective-tissue growths. Yoshida also noted, in a few of his animals, papilloma formation in the stomach and bladder, and bladder tumours were later obtained with 2 : 3′-azotoluene.

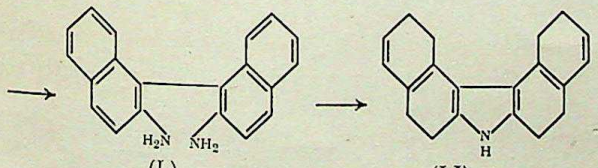
In other attempts to produce bladder cancer, Cook, Hewett and Kennaway selected the three *azonaphthalenes*, on the supposition that these might arise by oxidation of naphthylamines, and so be present in the crude bases which are a factor in the occupational incidence of the disease in chemical workers. No bladder tumours were obtained, but liver changes in mice, similar to those induced by the azobenzene derivatives, resulted from treatment with 2 : 2′-azonaphthalene (XLVIII). Azo compounds may be reduced to amines by way of the hydrazo compound (e.g. XLIX), and since this is susceptible to rearrangement, tests were made with the compound which might thus be expected, viz. 2 : 2′-diamino-1 : 1′-dinaphthyl (L).



(XLVIII)
2 : 2′-*Azonaphthalene*



(XLIX)
2 : 2′-*Hydrazonaphthalene*



(L) (LI)
2 : 2′-*Diamino*-1 : 1-*dinaphthyl* 3 : 4 : 5 : 6-*Dibenzcarbazole*

This induced liver tumours with even greater facility than 2 : 2′-azonaphthalene, a significant finding, since the diaminodinaphthyl readily undergoes deamination to 3 : 4 : 5 : 6-dibenzcarbazole (LI), which itself produces liver tumours, as well as skin cancer and malignant connective tissue tumours, in mice. These relations are obviously compatible with a suggestion that 2 : 2′-azonaphthalene is not inherently carcinogenic, but acts by a transformation to dibenzcarbazole; they thus provide some indication of a remarkable linkage between carcinogenic substances of the azo class and the polycyclic compounds.

The carcinogens are notable among chemical agents in producing a permanent transformation in the growth properties of cells. The chief feature of the new cell type is an increased *autonomy*, which shows itself by growth and invasiveness, independently alike of the further presence of the carcinogen or of the needs of the body as a whole. How is the change produced? From present evidence the essential influence of the carcinogen is to restrict normal cellular growth. The interference is characteristic in that no escape or easy acclimatization seems possible. At length, however, the biological response does occur, not as a continuous adaptation, but rather as a comparatively sudden break, which permits the cell to achieve independence in an environment still unpropitious for the normal form. Once emerged, growth of the new cell strain proceeds indefinitely, both in the same host and when carried through a series of healthy animals by transplantation—where it develops according to its new constitution and continues to exhibit an astonishing degree of constancy and specificity. As to the genetic nature of the change, many questions remain to be answered. Whatever the outcome, there can be no doubt of the fundamental character of these problems, transcending even their interest for medicine. There is, however, a need for more effectively integrating the subject with biology as a whole. When this is accomplished, the greatest contribution of such studies may yet be seen in the light they shed on cellular growth and variation in general, of which the problem of tumour induction is only a special part.

If we believe (with Rous) that the experimental pathologist must in the end express himself as surely as the artist, then here at least he has a prospect of success!

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Surface tension and its measurement

ALLAN FERGUSON

There are many and serious gaps in the literature relating to surface tension. For example, there is a real need for systematic measurement of the relation between surface tension and temperature for the members of certain homologous series of pure organic compounds: such data would be of great theoretical and practical importance. Professor Ferguson shows that precise determinations of surface tension can be made with very simple apparatus.

The chief object of this article is to point out some of the gaps in our experimental knowledge of surface tension and to show how these gaps may be filled by experiments carried out with the aid of very simple apparatus, which apparatus is, however, capable of producing results having a high degree of precision.

That the surface separating a liquid from a gas (or the surface separating two immiscible liquids) behaves as if it were in a state of tension may be deduced from everyday observation; the spherical shapes of raindrops or of small globules of mercury, in which the 'flattening' effect of the force of gravity, which depends on the volume, is negligible compared with forces depending on surface effects, are cases in point. Nor are qualitative reasons far to seek. If we admit the existence of forces between molecules very great at small distances, but falling off very rapidly with increase of distance, we see that we may draw round any molecule in a liquid a *sphere of molecular attraction* whose radius is such that molecules within the sphere may be regarded as exerting sensible forces on the molecule at the centre, molecules outside the sphere exerting no appreciable force on the centrally situated molecule. It is clear that a molecule situated well within a liquid will, on the average, experience no resultant force due to the attractions of its neighbours. It is otherwise with a molecule in the liquid surface, or at a distance from the surface less than the radius of the sphere of molecular attraction; a molecule so situated will experience an inward force perpendicular to the surface. Hence, to bring more molecules into the surface—that is to extend the surface—demands the expenditure of work, and *to this extent* the surface behaves like a stretched elastic membrane and tends to contract. The analogy must not be pushed too far, and the picture of a liquid as surrounded by an elastic skin is a fiction which may on occasion prove harmful. The considerations just mentioned show that the surface is the seat of energy, and the concept of the *free energy* per unit area of the surface—that is the maximum work obtainable in an appropriate isothermal transformation—provides a very powerful weapon with which to attack surface problems. The concept of surface tension is, however, a very useful one, and we shall for the most part employ it in what follows.

We assume, then, that across a line of length ds drawn in a liquid surface there is exerted a force equal to γds, perpendicular to the line and in the tangent plane to the surface; if the surface is that separating the liquid from air, or from its saturated vapour, γ is termed *the* surface tension of the liquid.

A simple application of molecular theory, or an appeal to direct experience, shows that a liquid meets a solid at a definite angle, which may be acute or obtuse. For many liquids in contact with glass this contact-angle is zero.

Again, on the concave side of a contractile surface, there must be a positive pressure excess which may be shown to be equal to $\gamma(1/R_1 + 1/R_2)$, where R_1 and R_2 are the principal radii of curvature at the point at which the pressure excess exists. If the surface is part of a sphere, $R_1 = R_2 = R$, say, and the pressure excess becomes $2\gamma/R$. In the particular case where the surface is plane, $R_1 = R_2 = \infty$ and the pressure excess is zero.

Bearing this in mind, it is easy to see why, and to what height, a liquid having an acute, or zero, contact-angle with glass will rise in an open vertical capillary tube standing in a vessel containing the liquid.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

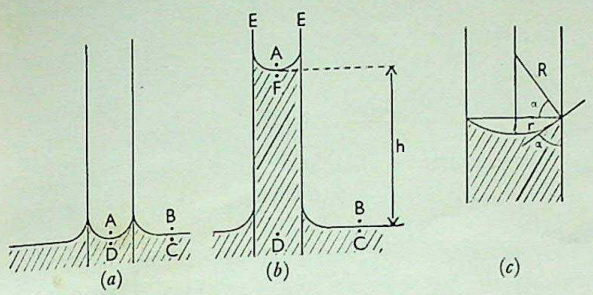


FIGURE 1

In figure 1 (*a*) we see an impossible position of equilibrium, for the liquid inside the capillary tube meets the glass at a constant angle α, and a curvature, which will be spherical if the bore of the tube is small enough, is imposed on the liquid within the tube. Now, since the surface of the liquid at C is plane we have:

Pressure at C = Pressure at B = Pressure at A
= Atmospheric pressure.

But, the meniscus in the tube being concave, the pressure at A exceeds the pressure at D by the amount $2\gamma/R$; so that we have two points, D and C, at the same level in a homogeneous liquid and at different pressures. This is impossible and the liquid must rise through a height h [figure 1 (*b*)] sufficient to produce a pressure ($g\rho h$) which will bring the pressure at D up to atmospheric value. Equating these expressions for the pressure excesses we have

$$2\gamma/R = g\rho h, \text{ or } \gamma = Rh\rho g/2$$

If the contact-angle is α and r is the radius of the tube, we have, from figure 1 (*c*):

$$r = R \cos \alpha, \text{ and } \gamma = rh\rho g/2 \cos \alpha.$$

If the liquid wets the tube, $\alpha = 0$ and we have the well-known result

$$\gamma = rh\rho g/2.$$

All this is fairly obvious, but it serves to bring out the point that in the practice of the capillary-rise experiment the two quantities measured are a pressure excess ($g\rho h$) and a curvature ($2/R$), and the ratio of these two quantities determines the surface tension. The necessity for measuring the density of the liquid under test arises from the fact that the *liquid acts as its own manometer*. If, then, we measure the pressure excess by some other method, as, for example, by applying pressure at the upper end (EE) of the tube until the meniscus is forced down to the position shown in figure 1 (*a*), we can measure the pressure required on an independent (and possibly more sensitive) manometer, and a knowledge of the density of the liquid under test is not necessary.

Let us apply these principles to a specific problem. Given a small quantity of a liquid, say a cubic centimetre, or even so little as that rather vague quantity a minim or drop, is it possible to make a precision determination of its surface tension? Figure 2 shows a simple form of apparatus by which such measurements may be easily and rapidly made. The figure is more or less self-explanatory. The pressure-bottle and manometer on the right-hand side of the drawing are

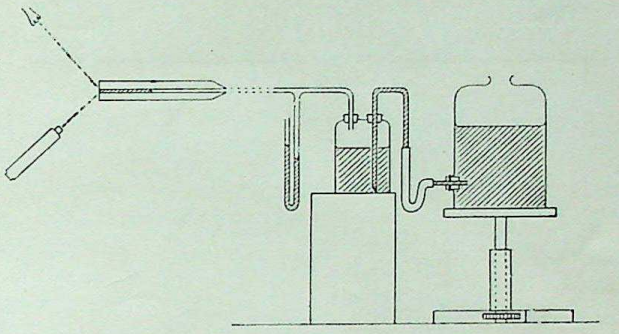


FIGURE 2

connected to a *horizontal* thick-walled capillary tube, of about a millimetre bore, which is shown on an enlarged scale on the left-hand side of the drawing. The end of this tube is ground flat to a matt finish and the short thread of the liquid under test is introduced into the tube. By raising the pressure-bottle shown on the extreme right of figure 2, the thread of liquid may be forced along the capillary until the meniscus at the open end is accurately *plane*. This position may be judged with very considerable accuracy by watching, through a low-power microscope or lens, the illumination of the meniscus provided by a 6-volt lamp. Figure 3 (*b*)–(*f*) shows a series of photographs of the end of the capillary: (*b*) and (*c*) show concave menisci, (*e*) and (*f*) convex menisci, and (*d*) shows the plane position in which the meniscus appears uniformly illuminated. The corresponding pressures read on an aniline manometer are shown in Table 1:

TABLE 1

Photograph	*b*	*c*	*d*	*e*	*f*
Pressure (cm. aniline) ..	2·689	2·836	2·887	2·955	3·108

It must not be assumed that these steps of pressure in any way represent the delicacy of the setting, which is very sensitive and clear-cut. The steps are shown at intervals of 0·5 mm. pressure-head or thereabouts to exhibit more clearly on the photographs the march of the

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

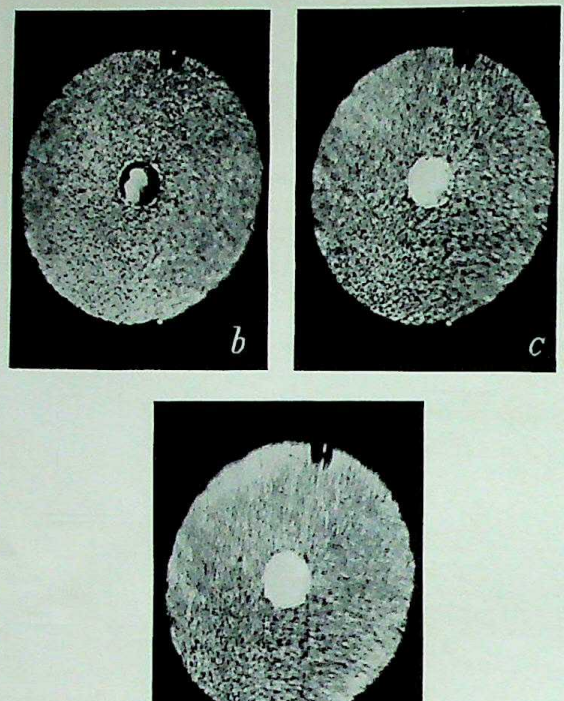


FIGURE 3

observed phenomena. It is obvious that the bore of the capillary must be small in order to ensure that there is no serious gravitational distortion of the meniscus—that is, to ensure that the meniscus may be assumed to be a segment of a sphere. This question has been fully investigated (Ferguson and Kennedy, 1932), and it has been shown that tubes up to 1 mm. bore may safely be used. It is clear from figure 4, which shows the horizontal capillary with the thread of liquid exhibiting a plane meniscus at the open end of the tube, that the pressures at D, C, and B are all equal and equal to the atmospheric pressure; that the pressure at A is therefore greater than atmospheric pressure by $2\gamma/r$, where if we assume a zero contact-angle the meniscus is hemispherical, and r is to be identified with the radius of the tube. But (*see* figure 2), the pressure at A is also seen to be greater than atmospheric pressure by $g\rho h$ where h is the pressure-head read on the manometer and ρ the density of the manometer liquid. Hence we have

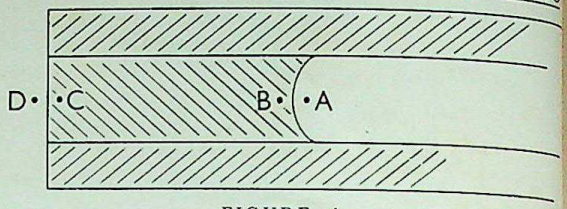


FIGURE 4

$$2\gamma/r = g\rho h \text{ or } \gamma = rh\rho g/2$$

We have assumed a zero contact-angle, and in fact research has shown that a zero contact-angle with glass exists for many organic liquids. The relevant article in International Critical Tables (1928) lists a small number of liquids for which this has been proved directly, and proceeds: 'That α for liquid-to-glass is zero . . . is indicated in the case of about 100 other liquids by the data used in compiling these tables, which show that the surface tension determined by the capillary height method on the basis of the assumption that α is zero is the same as the value obtained by the drop-weight method or by the bubble-pressure method.' Since these last-named methods are independent of the contact-angle, this is unimpeachable evidence.

It is important to be able to make measurements of the variation of surface tension with temperature, and a convenient arrangement for the purpose is shown in figure 5. This represents a simple form of furnace consisting of a brass tube 10 cm. long and 3 cm. in diameter overwound with nichrome wire. The furnace was closed with corks bored to accept the horizontal capillary which projected from the furnace at both ends. Temperatures were read by a chromel-alumel thermocouple, and for measurements over a temperature range of, say, 15° to 70° C. this arrangement of the tube was adopted. For substances which melt at a fairly high temperature

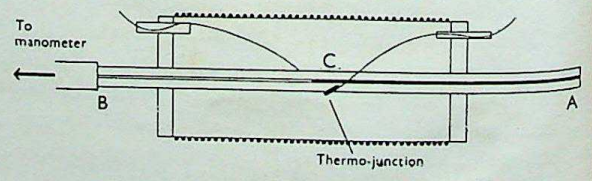


FIGURE 5

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

(e.g. 100° C.) the open end of the capillary was contained within the furnace, and the corresponding end of the furnace closed with a plate of optical glass through which the planeness of the meniscus at the end of the capillary within the furnace could be conveniently observed. Figure 6 shows the arrangement adopted for the measurement of the surface tensions of water and of heavy water.

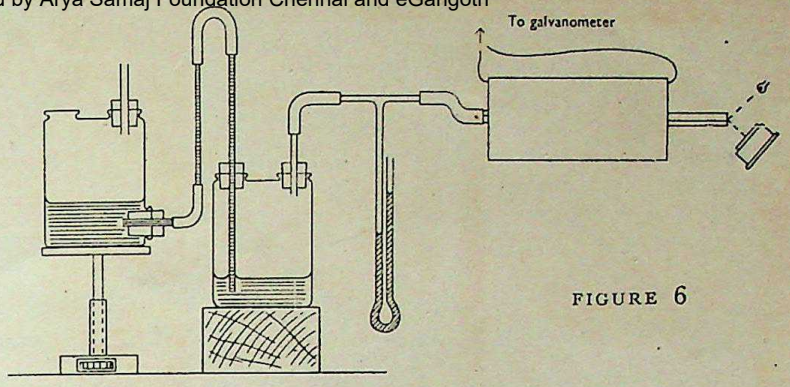


FIGURE 6

And now, having described a practicable and simple apparatus, we may ask: What results have been obtained by its use and what new results is it profitable to seek?

In the first place, it may be said at once that, despite the thousands of measurements that have been made, there are many and serious gaps in the literature, and that many of the measurements listed in tables have small value, consisting, as they do, of records of measurements made at one or two temperatures on isolated, or unrelated, substances. Anyone who will undertake the measurement of the relation between surface tension and temperature for the members of a homologous series of carefully purified organic compounds will provide data of great practical and theoretical value.

It may be remarked here that the practice of representing surface tension–temperature results by such a formula as $\gamma = \gamma_0 (1 - at)$ is to be deprecated. The formula will not bear extrapolation. Remembering that surface tension vanishes at the critical temperature, we see that, if such a formula is valid, $t_c = 1/a$, and values of t_c calculated in this way are wildly erroneous. van der Waals (1894) proposed a formula $\gamma = \gamma_0 (1 - bt)^n$, which passed unnoticed and was rediscovered independently by the writer of this article (Ferguson, 1916). This formula, which is valid for unassociated liquids only, represents the relation between surface tension and temperature over the whole range of existence of the liquid, from freezing-point to critical temperature. To a first approximation the value of n is the same for all liquids and may be taken as equal to 1·2. If the highest accuracy is desired, account must be taken of the small variations of n from liquid to liquid. If the formula be written $\gamma = \gamma_0 (1 - b\theta)^n$, where θ stands for the absolute temperature (t representing Centigrade temperature), then γ_0 stands for the free surface energy of the supercooled liquid at absolute zero and is an important constant of the liquid. The variation of its value for the different members of a homologous series is a property the study of which demands investigation. The quantity b in either formula is accurately the reciprocal of the critical temperature, and it becomes possible to determine the critical temperature of an unassociated liquid from observations of its surface tension made over a relatively restricted range of temperature, after determining the constants γ_0, b and n in the formulae just cited. The accuracy with which the critical temperature is represented by $1/b$ is shown in Table 2:

TABLE 2

Substance	n	b	$t_c = \frac{1}{b}$	t_c—obs.	Diff.
			°	°	°
Ether	1·248	·005155	194	193·8	+0·2
Benzene	1·218	·003472	288	288·5	−0·5
Chlorobenzene	1·203	·002793	358	359·2	−1·2
Carbon tetrachloride ..	1·206	·003553	281·5	283·1	−1·6
Methyl formate	1·210	·004695	213	214·0	−1·0
Methyl acetate	1·200	·004274	234	233·7	+0·3
Methyl propionate ..	1·202	·003891	257	257·4	−0·4
Methyl butyrate	1·195	·003559	281	281·3	−0·3
Methyl isobutyrate ..	1.228	·003731	268	267·6	+0·4
Ethyl formate	1·187	·004255	235	235·3	−0·3
Ethyl acetate	1·217	·003984	251	250·1	+0·9
Ethyl propionate ..	1·192	·003663	273	272·9	+0·1
Propyl formate	1·231	·003774	265	264·9	+0·1
Propyl acetate	1·204	·003623	276	276·2	−0·2

Mean value of n = 1,210.

For associated liquids no such formula holds and it is difficult to devise a formula which will bear extrapolation. Through the kindness of Imperial Chemical Industries the writer was some time ago supplied with a sample of heavy water of 99·2 per cent. purity, for the purpose of determining its specific heat, and a determination of its surface tension was also made (Cockett and Ferguson, 1939). Some previous observers had reported a very low surface tension for deuterium oxide, viz. 67·8 dynes per centimetre at

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

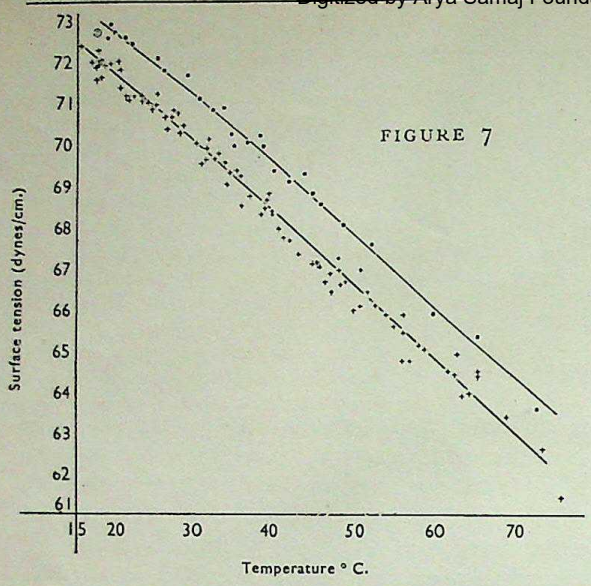


FIGURE 7

20° C. as compared with 72·8 dynes per centimetre for the surface tension of ordinary water at this temperature. Other observers had found no appreciable difference between the surface tensions of ordinary and heavy water. The problem was investigated by means of the apparatus shown in figure 6. The results obtained may be summed up in equations of the form $\gamma = A - Bt^n$, where, for ordinary water, A = 75·23, B = 0·0667, n = 1·20; for heavy water, A = 74·64, B = 0·1082, n = 1·10. The results obtained, and the agreement between the observed and calculated values, are shown in Table 3. Figure 7, which also shows the scatter of the observations, exhibits the differences graphically.

TABLE 3

Heavy Water				Ordinary Water			
t	γ obs.	γ calc.	Diff.	t	γ obs.	γ calc.	Diff.
° C.				° C.			
12·1	72·88	72·96	− 0·08	17·3	72·84	73·19	− 0·35
15·2	72·40	72·48	− 0·08	20·4	72·75	72·74	+ 0·01
20·1	71·97	71·70	+ 0·27	25·5	71·94	71·98	− 0·04
24·0	71·50	71·07	− 0·02	28·6	71·86	71·50	+ 0·36
30·1	70·17	70·06	+ 0·11	30·1	71·20	71·27	− 0·07
35·0	69·51	69·24	+ 0·27	34·5	70·35	70·56	− 0·21
39·5	68·44	68·47	− 0·03	38·4	70·07	69·92	+ 0·15
45·0	67·22	67·51	− 0·29	44·6	68·86	68·88	− 0·02
50·8	66·18	66·50	− 0·32	50·0	68·13	67·94	+ 0·19
55·0	65·63	65·75	− 0·12	60·2	65·93	66·11	− 0·18
61·9	64·54	65·52	+ 0·02	65·7	65·39	65·11	+ 0·28
64·5	63·59	64·05	− 0·06	73·1	63·60	63·99	− 0·39
69·0	63·37	63·24	+ 0·13				
73·5	62·66	62·42	+ 0·24				

It has been remarked that for substances which melt at relatively high temperatures the arrangement of the furnace and tube must be modified as shown in figure 8. This arrangement has been

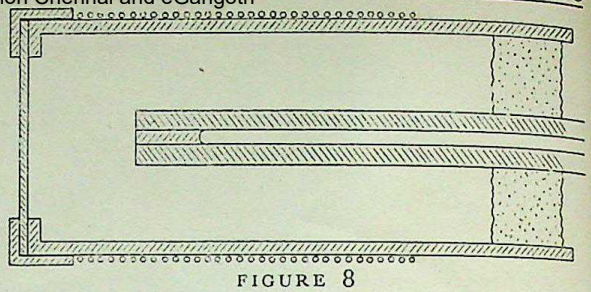


FIGURE 8

used (Ferguson and Kennedy, 1938) to study the interesting variations of surface tension with temperature which occur in the case of liquid crystals—substances that melt to form doubly refracting liquids which on further heating lose these doubly refracting properties at a definite transition temperature. Such substances are anisaldazine, *p*-azoxyanisol and *p*-azoxyphenetol, all

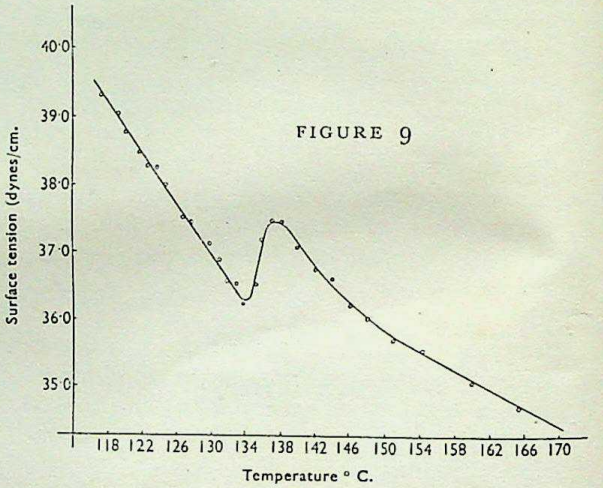


FIGURE 9

of which have been investigated. The curve for *p*-azoxyanisol is shown in figure 9. The transition temperature is 135° C., and it will be seen that in the neighbourhood of this temperature there is a marked increase of surface tension with increase of temperature. This remarkable phenomenon is exhibited by all the liquid crystals examined and demands theoretical investigation.

Applications could be multiplied *ad libitum;* but this article will have served its purpose if it has shown that a wide field of research exists in which most useful results may be obtained by relatively simple apparatus and technique.

REFERENCES

COCKETT and FERGUSON. *Phil. Mag.*, 1939, **27**, (7), 685.
FERGUSON. *Phil. Mag.*, 1916, **31**, (6), 37.
FERGUSON and KENNEDY. *Proc. Phys. Soc.*, 1932, **44**, 511.
Idem. Phil. Mag., 1938, **26**, (7), 41.
International Critical Tables, 1938, **4**, 434.
VAN DER WAALS. *Zeitschr. phys. Chem.*, 1894, **13**, 716.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

THE PRESENT POSITION OF EVOLUTIONARY THEORY

Evolution: the Modern Synthesis, *by J. S. Huxley. Pp.* 645. *George Allen and Unwin Limited, London.* 1942. 25*s. net.*

This is a very important book—important for being exactly what its author claims: a synthetic account of the modern view of the most important of biological problems. It comes at a very interesting time in the development of our understanding. Until about twenty years ago, our knowledge of the fundamental processes of evolution remained almost where it had been in Darwin's time. The only 'advance' had centred round the emphasis on the half-truth of discontinuity in variation and the theoretical application of an over-simplified Mendelism. The true implications of the new knowledge of heredity were, perhaps, first glimpsed by Tchetverikov, who, shortly after the first phase of the great Russian revolution, pointed out that in animal populations too the full potentialities do not lie open to inspection at the surface but may exist in a hidden, recessive form for many generations until, following some change in circumstances, they become advantageous and spread through the whole species. This line of thought initiated two active schools of work—the theoretical investigations of Fisher, Haldane, and Wright, and the practical investigation of natural populations by Dobzhansky, Timoféef-Ressovsky, Dubinin, Gordon, and others. Meanwhile, geneticists such as Stern and Muller were developing the idea of the 'genotypic milieu' and the mutual interaction of genes; the evolutionary bearings of their ideas were incorporated by Fisher and Wright into their mathematical treatment of natural selection. Another strand to be woven into the fabric came from the investigations of systematists into the geographical variation of animals; stimulating, and itself stimulated by, the mathematical treatment of Wright, it issued in the most important single new theory, that of the 'drift' of populations under the guidance, not of natural selection, but of chance.

In the last twenty years, then, several new avenues have opened up and the first steps have been taken along each of them. Huxley, with his very wide reading and a true insight into the real nature of the advance, fits into the framework of his synthesis a richer accumulation of facts than is found in the only other comparable book in English, Dobzhansky's *Genetics and the Origin of Species*. He is particularly successful in his treatment of systematic and ecological data, which are often too little known by geneticists. And he has not only a story to tell of past achievements, but many doors to open towards the future. It is only the first crop which has yet been taken off the fields spoken of above—there is much to do before we need think of leaving them fallow. And there are fields even more recently surveyed—the problems, discussed by Darlington, of the evolution of genetic systems themselves; and the old, but now perhaps rather less intractable problems, recently the subject of a book by Goldschmidt, of the limitations imposed by the developmental system on the variation available for evolution. Huxley's book is, in fact, something more than a synthesis in the chemical sense which implies the achievement of a fixed and determined goal; the unity which it records is a stage in an ever-deepening and developing knowledge.

C. H. WADDINGTON

ANIMAL INVADERS

Voles, Mice, and Lemmings, *by Charles Elton. Pp.* 496. *The Clarendon Press, Oxford.* 1942. 30*s. net.*

Overwhelming plagues of voles and devouring hordes of migrating lemmings—these are occurrences which have impressed observers from earliest historical times. They have often spelt ruin for the farmer, and have even forced their attention upon disinterested governments. In themselves they constitute a formidable challenge to the scientist, a challenge which is fully answered in this authoritative book.

Too often has it been supposed in the past that these mighty pulsations of nature are 'unnatural,' so quick is the human tendency to forget bygone disasters. In this book such prolific increases are placed in their proper perspective to the normal ebb and flow of animal, and particularly rodent, populations. The periodic fluctuations in the numbers of these small herbivores have an inevitable effect upon the abundance or scarcity of the many predators who, directly or indirectly, benefit from them. This is a theme which is followed out in a fascinating manner throughout the book.

Part I is concerned with the history of vole plagues in Central Europe and the means that have been used to combat them. Part II deals with rodent fluctuations in North-west Europe, including the famous lemmings of Scandinavia. In this section are also two important chapters on the new methods developed at Oxford to study the density of rodent populations. It might be said that these two parts illustrate in a very graphic manner the way in which animal ecology as an exact science is growing out of natural history.

Parts III and IV contain the most unusual feature of this book—the detailed analysis of wild-life cycles in Labrador and Ungava, derived from hitherto unpublished material in the trade archives of the Moravian Missions and the Hudson's Bay Company. Periodic oscillations, which had been demonstrated experimentally for the Oxford voles, stand out with almost startling clarity for some of the Labrador predators, which, in turn, were shown to depend on rodent cycles. Particularly noteworthy are the four-yearly cycle of abundance of the Labrador foxes and the ingenious methods Mr Elton has used to show that the fur returns are a reliable index of population density.

The original question as to the cause of these prodigious fluctuations in rodent numbers remains partially unanswered, but some promising lines of research are discussed.

It is hardly possible in the space of a short review to refer even in brief to the wealth of facts mustered in this book, nor is it possible to convey the vivid style in which it is written, a style enhanced by the author's inclusion of many contemporary notes and descriptions.

A. D. LEES

EXPLOSIVES FOR THE MILLION

Explosives: Tells of explosives, their magical creation, their fierce energy, their sudden disruption, their history and romance, and their uses in Peace and War, *by John Read. Pelican Series*, 1942. 9*d.*

Professor Read has found full scope for his skill as a dramatist, teacher, organic chemist, and historian in this book on explosives in the Pelican series. He develops the theme of the sun's energy, which, converted into organic energy in the leaves of plants, is by-passed into explosives by various

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

arts developed by man. Nature in her wisdom 'has refrained from including in her lavish chemical cornucopia any substance of an explosive nature,' but Nature's wilful child, like unto a 'Maxwell's demon,' has sorted out those bodies which can be prompted to release their energy with cataclysmic violence. The organic chemist, by providing buffers of nitrogen atoms, has introduced the combustible and the supporter of combustion into the same molecule, which makes possible a speed of combustion limited only by the velocities of elastic waves. Derived in the main from carbohydrates, fats, and coal, the nitro-bodies form the principal classes of explosives, but rarely yield more than 50 per cent. of the energy available in the parent substances and atmospheric oxygen. Thus, although the chemical bond groans under the strain imposed upon it, the organic chemist has still worlds to conquer.

The inorganic chemist has not been idle, for he has provided the 'fifth columnists' of the explosive world, azides and fulminates, which are employed to release the energy conserved by the organic chemist. He can claim most of the incendiaries and might have claimed the first explosive of all, except that in the thirteenth century alchemy had not yet been differentiated into its component parts. It is now exactly 700 years since Roger Bacon 'made known' the composition of gunpowder. This anniversary is fittingly celebrated by a historical chapter on gunpowder from the author's pen.

This is a book which combines the elements of a textbook and a novel. It is a story of the romance of chemistry that does not burke an account of its shorthand, its terminology and its method of formulation, which are explained to the reader in imagery with which he is familiar from practical experience. It is opportune, and practical in its outlook. It is not confined to the chemistry of explosives, but describes and illustrates methods of manufacture and assembly. The expert will find facts in it that are new to him, and the Home Guard much that will explain the vagaries of the weapons entrusted to his inexperience. The latter may even learn of the means to increase his arsenal, although warned by the author of possible fatal consequenecs.

It is sad to reflect that, but for the requirements of nitrocellulose for war purposes, this might truly have been a book for the million.

W. E. GARNER

CELLULOSE

An Introduction to the Chemistry of Cellulose, *by J. T. Marsh and F. C. Wood. Pp. xv* + 512, *with* 24 *plates and* 145 *figures. Chapman and Hall Limited, London. Second edition*, 1942. 28*s. net.*

The chemistry of cellulose and cellulose derivatives is both an extensive and a specialized study. It is also a study in which very remarkable progress has been made within the last few years. Quite apart from its technical importance, it has a general interest for the organic chemist, the biochemist, and the biologist. From these facts the need for an authoritative introduction to the subject becomes apparent, and when the present book was first published, in 1938, it was deservedly welcomed. The authors have a probably unrivalled knowledge of cellulose chemistry, pure and applied, while their familiarity with the relevant literature appears to range from A to Z without a gap. Though the book is modestly described as introductory, and though in fact it does start *ab initio*, any reader who masters it will have acquired a comprehensive working acquaintance with the whole field. A pleasing—and valuable—feature of the book is the readable style in which it is written. In this new edition the latest developments in cellulose chemistry have been incorporated; otherwise it closely follows the lines of the successful original edition of 1938.

RADIO COMMUNICATION

Short-wave Wireless Communication, *by A. W. Ladner and C. R. Stoner. Pp.* 573. *Chapman and Hall Limited, London. Fourth edition*, 1942. 35*s. net.*

Every radio engineer and physicist knows 'Ladner and Stoner,' in the form of one of the earlier editions, and to them the publication of a fourth edition is a matter of the greatest interest. The contents are restricted to the title-subject of 'short-wave wireless *communication*' in its narrowest sense, and there is no mention of some of the most interesting applications of short-wave techniques, such as aids to aerial navigation and blind landing, direction and position finding, and television aerials, even in their well-known pre-war aspects. In the communication field one notices the absence of any discussion of the very interesting systems of frequency modulation now in use in America. Curiously enough, although these matters of great interest are neglected, a chapter of twenty pages is devoted to 'high-frequency therapeutic apparatus.'

In general, the treatment of the circuit problems of high-powered oscillators, modulators and amplifiers, which form a large part of the book, is full and satisfying; while the accounts of transmission lines, aerials, and propagation are full but rather superficial, since little attempt is made to explain the underlying physical principles. The account of the super-regenerative receiver appears to be erroneous.

In summarizing, it may be said that the book is a very good and, on the whole, readable account of the subject as seen from the limited point of view of the Marconi Wireless Telegraph Company; but to the radio physicist in particular that point of view appears to be an unnecessary limitation of the title 'Short-wave Wireless Communication.'

J. A. RATCLIFFE

THE SCIENTIST AND THE STATE

The Scientific Life, *by J. R. Baker. Pp.* 154. *George Allen and Unwin Limited, London.* 1942. 7*s.* 6*d. net.*

In this stimulating and provocative book Dr Baker throws down the gauntlet to those men of science who do not conceal their admiration of totalitarianism and would like to see science organized under state control. He is able to show, in a manner that most readers will find convincing, that science flourishes best in an atmosphere of freedom; that most of the greatest scientific discoveries have been made by individuals and not by teams or groups of workers; and that there is a very real danger of science becoming fettered by bureaucratic control, professedly for her own good. But Dr Baker has made the tactical error of overstating a sound case and has thus unnecessarily laid himself open to grave criticism upon several points. In general, however, the book is both welcome and timely; Dr Baker wields a stout lance, and if he sometimes tilts at a windmill it may be because he has reason to suspect camouflage.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME II APRIL 1943 NUMBER 6

Chemotherapy

Dramatic progress in many directions continues to be made in the applications of chemistry and biochemistry to the eradication of disease. We hope in due course to publish authoritative articles dealing with many of these topics in detail. A definition of the scope of true chemotherapy is hard to frame, and the progress of research may soon pass the boundaries of artificial limitation. We may assume, however, that the term implies the cure of infections caused by micro-organisms with the aid of substances of known or partly known constitution.

The father of the subject was Paul Ehrlich, who noted in 1891 that the malarial parasite is stained by methylene blue; he then tried to find dyes and, later, what may be called colourless dyes, which would kill the micro-organisms without damage to the host. Methylene blue itself was found to have some action against quartan malaria. Perhaps the first notable result was the discovery of trypan red (1904), which cured an otherwise mortal infection of mice by trypanosomes. The organic arsenicals, atoxyl (Thomas, 1905), salvarsan, neo-salvarsan, tryparsamide, etc., are milestones along the road opened up by Ehrlich, and some of them are still essential to the physician. Analogously, organic antimonials have been introduced into medicine, and in retrospect we cannot ignore the mercurial treatment of syphilis, sometimes attributed to Paracelsus.

The appearance of Bayer 205 for the treatment of sleeping sickness was probably the direct result of Ehrlich's work; it was a great step forward because this complex derivative of benzene and naphthalene contains no arsenic or similar toxic element. In the last few years King, Ewins, and Warrington Yorke have shown that certain aromatic diamidines are highly effective against various protozoa.

We can make only a brief reference to the highly important subject of the chemotherapy of malaria. Quinine retains its position in the treatment of acute infections, and though many active analogues of the alkaloid are known, none has been introduced into practice. The more successful synthetic antimalarials appear to have been developed by following up Ehrlich's observation with methylene blue. They are plasmoquine (1926), a quinoline derivative, which is said to destroy the sexual form of the parasite (crescent or gamete), and atebrin (1932), an acridine derivative, which like quinine attacks the asexual form (schizonts). We owe these resources to the outstanding work of Roehl and Schulemann and their colleagues. Many similar drugs have been recommended and the present time is one of intensive research, due in part to the occupation of the Dutch East Indies by the Japanese.

The guiding hypothesis in this period was the idea of direct action on the micro-organism. Ehrlich imagined that the cells of the organism to be attacked contained various receptor groups of protein or enzyme molecules, and considered his problem to be the recognition of these groups and the elaboration of suitable toxic substances to combine with them.

For a long time there was no chemotherapy of bacterial infections, although the possibility was recognized after it had been shown that acriflavine or proflavine need not kill trout ova which they nevertheless sterilize (Blake), and after Morgenroth and Levy cured mice, experimentally infected with pneumococci, by means of ethyldihydrocupreine. These observations were of no practical importance (except for local infections), and the discovery of prontosil by Domagk brought about a revolution, not only in treatment but also in the attitude of biologists to the study of chemotherapy.

Prontosil is an azo-dye, and very soon Tréfouel and others found that one of its components,

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

sulphanilamide, is alone responsible for its activity. Sulphanilamide is relatively non-toxic to man and is used in massive doses against virile strains of haemolytic streptococci. It has reduced the mortality of puerperal fever to an amazing extent. The drug is also of value in keeping wounds clean, provided that the greater part of the infective material has been removed.

Sulphanilamide is not effective against meningococci, gonococci, and pneumococci, but certain derivatives such as sulphanilylaminopyridine (M. and B. 693, Ewins and Phillips), sulphathiazole, and sulphadiazine are now among the physician's sheet-anchors in the treatment of meningitis, gonorrhoea and pneumonia. The cures brought about are often as magical as those of scurvy by vitamin C. Sulphanilylguanidine is claimed as a remedy for bacillary dysentery, and the sodium salt of acetylsulphanilamide is useful in combating certain infections of the eye. There is already an enormous literature of the sulphanilamides, but we may be sure that still better compounds of the series will eventually be found. It is even probable that a supply of the perfected drug will be kept in most households and will be taken when the need arises with as little compunction as an aspirin tablet. Sulphamethazine, recently introduced by British chemists, approaches this ideal on account of its low toxicity, and the results of further chemical trials will be scrutinized with great interest.

Several workers obtained extracts which antagonized sulphanilamide, and finally Woods (1940) showed that *p*-aminobenzoic acid counteracted the action of the drug. According to Fildes, who has extensively studied bacterial growth factors and growth inhibition factors, aminobenzoic acid is an essential metabolite, and sulphanilamide is bacteriostatic because it interferes with the normal growth-promoting action of this metabolite. Fildes has emphasized that here we must have the rational approach to research in chemotherapy, and the idea is being enthusiastically followed up by numerous investigators. For example, McIlwain has very recently shown that analogues of pantothenic acid possess bacteriostatic action in certain cases. Roughly the idea is that of the cuckoo in the nest, and it helps us to understand why the dosage of some of the newer remedies must be so high. A kind of mass action replacement of a normal essential for growth is involved.

Surely this would suffice for a few years' progress, but the story continues. In 1929 Fleming found that suitably grown *Penicillium notatum* produced an anti-bacterial substance, termed penicillin, which differed in important particulars from the sulphanilamides. Its action, though bacteriostatic rather than antiseptic, is not interfered with by bacterial extracts, pus fluids, or *p*-aminobenzoic acid. Florey and others showed how to prepare penicillin for therapeutic use and demonstrated its value clinically. The chemical constitution of this important substance has not yet been elucidated, but it is already certain that it is effective in very high dilution, that it is almost completely non-toxic, and that, unlike the sulphanilamides, it may be used against staphylococci. Somewhat similar properties, except in respect of toxicity, are claimed for gramicidin, which has been isolated from soil. It is a polypeptide containing tryptophan units.

The outstanding problems among bacterial infections are tuberculosis, typhoid, and cholera, and in each case there are indications that may be followed. The end is not in sight, but we are marching along a road that will lead to it. Witnessing the dawn of a day of hope we may be comforted by the reflection that these tragic years are making some amends by contributing to the alleviation of the sufferings of humanity. Chemotherapy is a benevolent legacy to posterity that will gather compound interest.

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Metals

SIR LAWRENCE BRAGG

We associate metals with hardness, toughness, and strength. But a curious paradox lies at the root of the valuable mechanical properties of the metallic state: in order to be strong, a metal must be weak. This paradox, and the equally surprising fact that, in a sense, metals are not true solids at all, are among the topics here discussed by Sir Lawrence Bragg.

(1) WHAT METALS MEAN TO US

We employ various materials to build or fabricate the many objects we use in everyday life, choosing those whose properties are most suitable for the purpose which the object has to serve. Certain of these materials have been used from the earliest times, such as stone, wood, leather, and animal or vegetable fibres, each with its own peculiar valuable properties. Stone resists crushing and is very durable and permanent, as indeed it must be, since it has so long resisted change as a part of the earth's crust. It is therefore ideal for walls and buildings, and very early in his history man discovered how to make artificial stones by burning clay, with the advantage that they could be given any desired shape, and made into bricks or given elaborate forms as pottery. Wood is strong and tough and light, it resists tension as well as compression, and is not brittle like stone. It forms beams and furniture and parts of tools or weapons. Leather is tough but at the same time it is flexible; it is ideal as straps or sheets. Vegetable fibres such as linen or cotton, and animal fibres such as wool and silk, owe their value to their flexibility and strength in resisting extension. They can be spun into yarn or rope, and woven into cloth. The technological age in which we are now living is replacing the natural products used by early man by a series of artificial products, but it is remarkable to see how in nearly every case we are copying Nature's materials. The wide use of concrete represents a developed art of making artificial stone. Artificial fibres such as rayon or nylon replace cotton, wool, and flax. Plastics are coming very much to the fore; they correspond to early man's use of horn, another substance with peculiar properties of toughness in all directions without the 'grain' of wood. For the most part we are following in the footsteps of our remote ancestors, though we can make for ourselves what they had to cull from wood and field. There are exceptions; for instance, we have discovered comparatively recently the number of uses to which natural rubber can be put, and are now making it artificially. This is a really new discovery; our ancestors had nothing with such remarkable powers of elastic stretching without breaking, and resistance to being abraded.

Metals represent one vast range of materials, however, which have no natural counterpart. They have to be won from the earth, where they exist in a cunningly hidden form. Mankind only slowly realized their potentialities. They were at first rare and precious, used for very special purposes. Great store was set by them, and trade routes sprang up for their commerce. It must have been by chance that some early Tubal-cain discovered that when certain stones were heated in the fire, a substance with hitherto undreamed of properties could be beaten out, and so became, as Genesis relates, 'an instructer of every artificer in brass and iron.' Modern civilization is based upon the use of metals to an extent which is always increasing at a truly extraordinary rate. Sir Thomas Holland, in reviewing our resources, states that far more metal has been taken from the earth by men since 1900 than in the whole of the previous history of mankind.

What gives metals this distinctive character we all recognize as 'metallic,' which makes them play a quite unique part in our material civilization?

Their most striking mechanical attribute is that they are hard and strong in resisting compression and extension, and that at the same time they are tough and can be distorted without breaking. They can be dented or hammered or drawn into wire, and so far from being weakened by maltreatment of this kind, they become even stronger than before. A stone is hard and strong, but once it yields it breaks completely; it is brittle. What new possibilities were opened up to primitive man when, instead of flint, he first came to know of a material for weapons and tools which was as hard as stone and yet could be relied on not to snap!

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Again, metals can be moulded to our purposes by heat. Familiarity dulls the keen edge of appreciation, but most of us can probably remember the thrill of seeing a blacksmith make a horseshoe, converting the strong iron into something as soft and pliable as clay by heating it red-hot. The final properties of steel depend on the history of its heat-treatment. A steel spring, if heated and cooled slowly, is relatively soft and can be bent into any desired shape, cut, or drilled. If it is heated and suddenly cooled or 'quenched' it becomes very brittle. Warm it up again to a relatively low temperature, and it becomes 'springy.' Or take the kind of iron from which files are made, containing a high proportion of carbon. If cooled slowly it is so soft that the teeth of the file can be cut on it. Heat it, and quench it by plunging it into brine, and it becomes glass-hard and fit for its work. It is such properties which make metals the ideal materials for the vast complex of machinery on which we now depend.

Metals are essential to us in another way now that we have made electricity our servant. They conduct electricity, and iron (along with some other elements) can be magnetized. A cable is laid across the Atlantic; in other words a few strands of copper wire are surrounded by a thin sheath of rubber composition and deposited on the sea floor. What a remarkable thing it is that if an electric current is fed into the cable in England, it prefers to travel along the wire to America rather than jump the intervening inch or so of insulator which is all that prevents it taking a short cut back home through the sea! I think it was Oliver Wendell Holmes who, on seeing a tram drawing its energy from a tenuous overhead wire, said it was power stripped stark naked. The possibility of sending messages and power by a metallic conductor has had incalculable social consequences. It has linked the world into an organic whole by providing it with a system of nerves by which the consequences of what happens in one part of the globe are immediately felt in other parts. Biologists rank living things in a scale of ascending complexity of their nervous systems; we are living in a world which has possibilities of much higher organized life than that of our forefathers, and we are trying to adjust ourselves to the new conditions, with shattering consequences. The use of metals has brought about the change. The present war is fought with weapons of metal made by metal machines; the possession of sources of metal determines its strategy; the whole world has been involved in it because of the metallic links which bind it together. One may say that the vastly increased use of metal has determined the character of the war, and to a large extent has been responsible for the social changes which have brought it upon us.

(2) THE METALLIC STATE

The science of chemistry is concerned with the compounds which are formed when the various elements are combined together. The atomic theory had its origin as an attempt by Dalton to explain the proportions in which the elements combine. More recently, physicists have studied the structure of the atom, and have gained a greater understanding of the forces which bind atoms together. It would take us too far to plunge into the theory of atomic structure in this article, but certain aspects of it may be recalled which indicate the fundamental nature of the metallic state.

The many different kinds of atom, some ninety odd in all, may be roughly divided into two great classes, electropositive and electronegative. The periodic table displays the elements ranged in ascending order of atomic complexity, and in it the inert gases which have no chemical affinities stand out as neutral landmarks at important points in the table. The atoms which occur after them in the table are markedly electropositive, those which come just before are equally markedly electronegative, and the character changes as one passes from one inert gas to the next in the series. Interpreted in terms of atomic structure, the electropositive atoms are those which easily part with one or more of the negative electrons surrounding the nucleus of the atoms, and thus change from neutral atoms into positively charged ions. The electro-negative atoms easily absorb one or more additional electrons into their structures, changing from neutral to negative in charge. These two classes are the Bulls and Bears of the atomic Stock Exchange; the one has electrons it is prepared to sell, the other lacks electrons and is willing to buy. The majority of elements are electropositive; they are the metallic elements.

To continue our broad generalization, which we will not confuse by the qualifications which would have to find a place in a more detailed account, there are three main types of compound, or association of atoms. They are illustrated in a pictorial way in figure 1.

The most simple is an association of electropositive and electronegative atoms. Common salt, NaCl, is an example. The electropositive

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

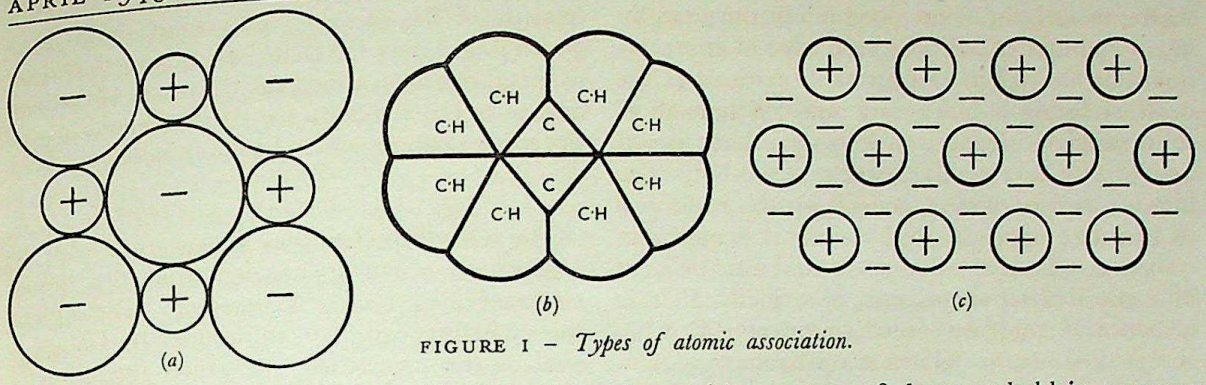


FIGURE 1 – *Types of atomic association.*

atoms of the metal sodium part with their electrons to the electronegative atoms of chlorine. The resulting positive sodium ions and negative chlorine ions are held together by electrostatic attraction, as in figure 1 (*a*), in a kind of chessboard pattern. Such a structure is typical of inorganic salts in general, although the negative unit is often a complex of several atoms.

Quite a different type of association is characteristic of organic compounds. Two or more electronegative atoms, both short of electrons, fuse their structures into an intimate combination. This tightly knitted whole, like that of naphthalene illustrated in figure 1 (*b*), is what the chemists term a 'molecule.' Such a molecule can go through physical adventures, such as melting, vaporizing, or being dissolved in a solvent, while still remaining an entity. The electronegative elements carbon, oxygen, and nitrogen have the strongest powers of forming such groups, and with a ballast of hydrogen they form the basis of the vast complex of compounds studied by the organic chemist.

In fibres, such molecules are incorporated in long chains by linking each to the next. In horn, and in some plastics, they are joined by side-links as well. Long chains with links free to rotate, so that they can wriggle, and joined only by infrequent side-bands, form a material with the properties of rubber. It can be seen that this power of linking on any number of atoms to the structure leads to an infinite variety of molecular forms. Nature has seized upon this possibility in order to construct the vast molecules of which living bodies are built, containing thousands of atoms, where the complexity is necessary to enable them to perform such varied functions.

The above may be called the plus-minus and minus-minus chemical compounds; there remains a third class, the plus plus, shown in figure 1 (*c*). It is composed of atoms all of which lose electrons easily. We may think of it as an array of positive ions, with a system of electrons held in common between them all. It is quite a different type of compound from those illustrated by (*a*) and (*b*). The relative numbers of atoms in (*a*) are fixed by the alternation of plus and minus, and in (*b*) by their association into definite family parties or molecules. In (*c*) it is possible to replace one kind of electropositive atom by another, as long as the newcomer is not too incompatible in size and other properties with its neighbours. When the atoms are all of one kind we call the structure a pure metal; when they are mixed we call it an alloy, and it is natural to find that the electropositive or metal atoms can be alloyed together in a wide range of proportions. The general cloud of electrons can drift through the structure, endowing the metal with its power of conducting electricity.

(3) A MODEL WHICH ILLUSTRATES THE METALLIC STRUCTURE

We have seen that the metallic state has certain peculiar features. In a sense metals are not true solids. There are no direct bonds between atom and atom binding the whole together. The positive ions actually repel each other, and are only held in a compact mass by the attraction of the negatively charged common system of electrons. This structure indicates the explanation of the most characteristic feature of a metal, the way in which it can be hammered or dented or rolled without breaking down its continuity. However the atoms slither over each other, the continuous electron cloud remains to hold all together. A metal is more like a crystallized liquid than a solid.

An immediate reaction to such a picture of a metal is the question why a metal has any strength at all if the atoms can slide over and past each other so easily. The answer is very interesting. If a pure metal is cooled from the molten state under controlled conditions so that the atoms are

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

built into a single perfect crystal, it has practically no strength at all. Professor Andrade wrote an article for the April 1942 number of ENDEAVOUR in which he described experiments on the slip of metal single crystals. It is a queer experience to handle such a crystal in the form of a long rod. It is as weak as a similar rod of plasticine and can be stretched at first by the fingers with hardly any resistance. Directly it is distorted by stretching, however, it becomes stronger, and finally when it is thoroughly maltreated it assumes the strong rigid character we associate with metal in the ordinary state. A simple experiment with a copper wire illustrates this feature well. If the wire is supported horizontally by one end and a Bunsen flame played along it, the wire becomes very soft. It does not become a single crystal, but it 'anneals' into a conglomeration of highly perfect crystals which show the effect. In this state, a very small weight hung on its end bends it over. Bend it back to the horizontal position, and it will support the weight. Bend it backwards and forwards a few times, and it becomes very stiff. 'Cold work' has made it strong.

A two-dimensional model of the metal structure can easily be made which illustrates these properties in rather a fascinating and suggestive way. Our model must have numerous 'atoms' of exactly equal size; these atoms must be round, they must slither over each other without any friction, and there must be some general force of attraction holding the whole together. Figure 2 shows a raft of tiny bubbles floating on the surface of a soap solution, which will do just what we want. The little bubbles all stick together by capillary forces, like the 'sixpence' in one's teacup when it is stirred. By blowing them through a small orifice under the surface with a constant pressure equal to about 20 cm. head of water, a remarkable constancy of size can be achieved. The perfection of the rows in the 'crystal' of figure 2 is evidence of the regularity. The bubbles are about 1 mm. in diameter.

A raft roughly rectangular in outline can be attached to supports on either side, and we can try the experiment of shearing it. Springs just lying on the surface of the solution make convenient supports because, by adjusting the tension, one can make the pitch of the spring fit a row of bubbles on either side. If now one spring is slowly moved tangentially, the raft at first strains elastically. After a certain amount of sheer strain, however, one can see a few bubbles on one of the free edges becoming unstable and slithering over each other, and then suddenly a movement runs along a row from one edge to the other across the raft, like a ladder in a stocking. The bubbles in turn 'move on one,' and when this movement has gone right across, the top and bottom of the raft become displaced by one bubble width relatively to each other. This can be repeated several times. Figure 3 shows typical rafts—(*a*) before and (*b*) after a succession of these movements of slip. When a single metal crystal is extended, as Professor Andrade has found, it does so by slipping along crystal planes as shown in the beautiful illustrations of his ENDEAVOUR article; in our two-dimensional model we have 'slip-rows' which behave in a similar way.

The graph in figure 4 shows how this phenomenon may be studied quantitatively. The ends of one of the springs are attached to a pair of long thin vertical glass fibres which are held rigidly at their far ends. A telemicroscope with a scale in its eyepiece is focused on one of these glass fibres, so that we can measure the force on this spring by watching the displacement of the fibre. The other spring is moved parallel to itself by a micrometer head. It is thus possible to establish a stress-strain curve as shown in figure 4, where the strain or relative movement is plotted horizontally and the stress measured by the bending of the glass fibre is plotted vertically. The upper graph runs from left to right. The raft is at first elastic as shown by the upward slope of the graph, until the point is reached where slip takes place, when the stress falls back to zero or even a little past the zero. As we continue to shear, it builds up again till further slip takes place. At the end of the upper graph the shearing movement was reversed, and the graph repeated in an inverted form.

In the next paragraph I wish to indicate the significance of this effect as regards the strength of a metal, but before leaving our model I would like to draw attention to some other suggestive features. In a single perfect crystal the atoms are arranged in absolutely regular rows and sheets.

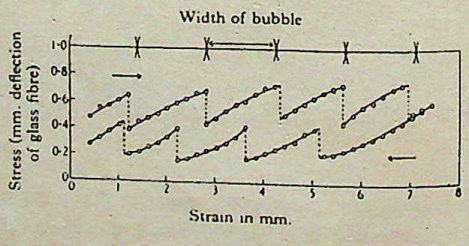


FIGURE 4 – *A stress-strain curve for the sheared raft. It yields each time the shearing movement increases by one bubble width.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

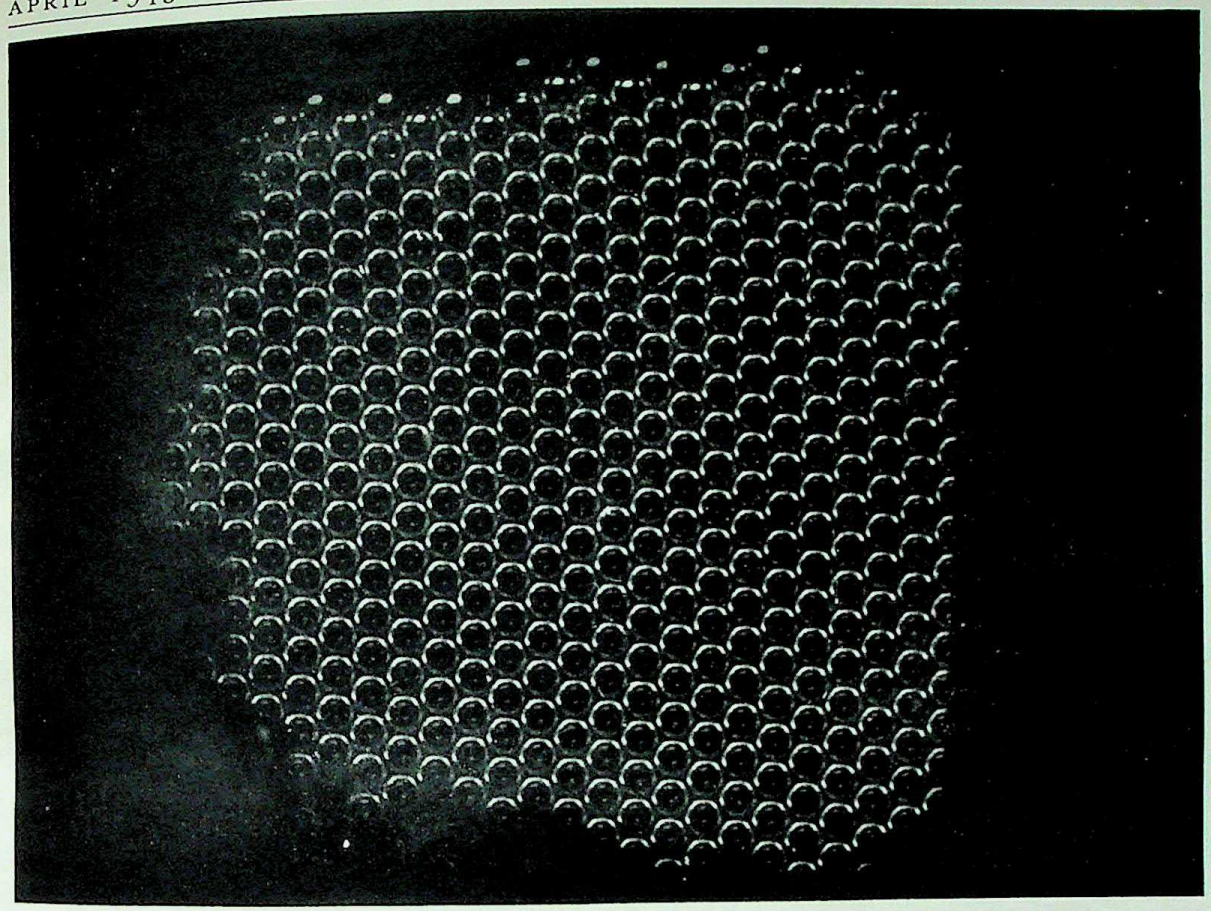
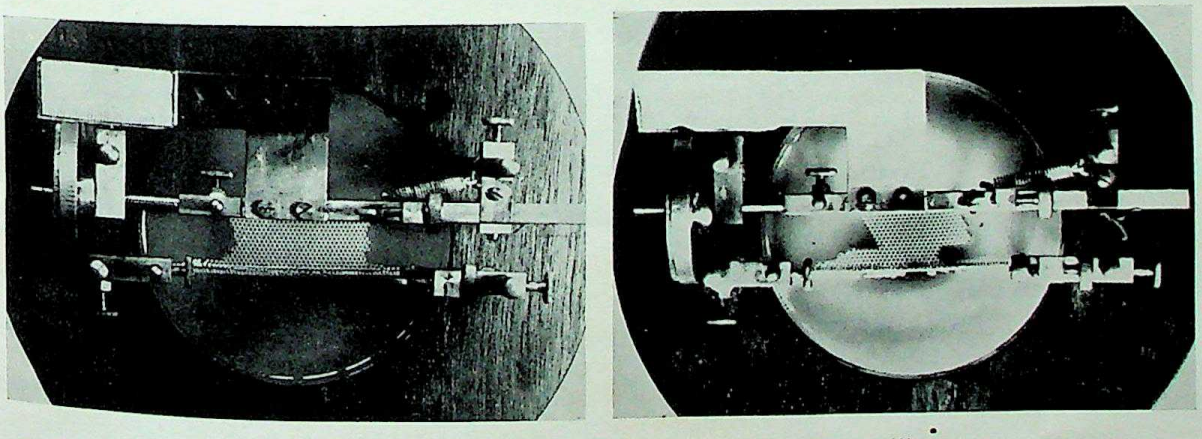


FIGURE 2 – *A perfectly crystallized raft of bubbles.*



(*a*) (*b*)

FIGURE 3 – *Rafts before and after a succession of 'slip' movements.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

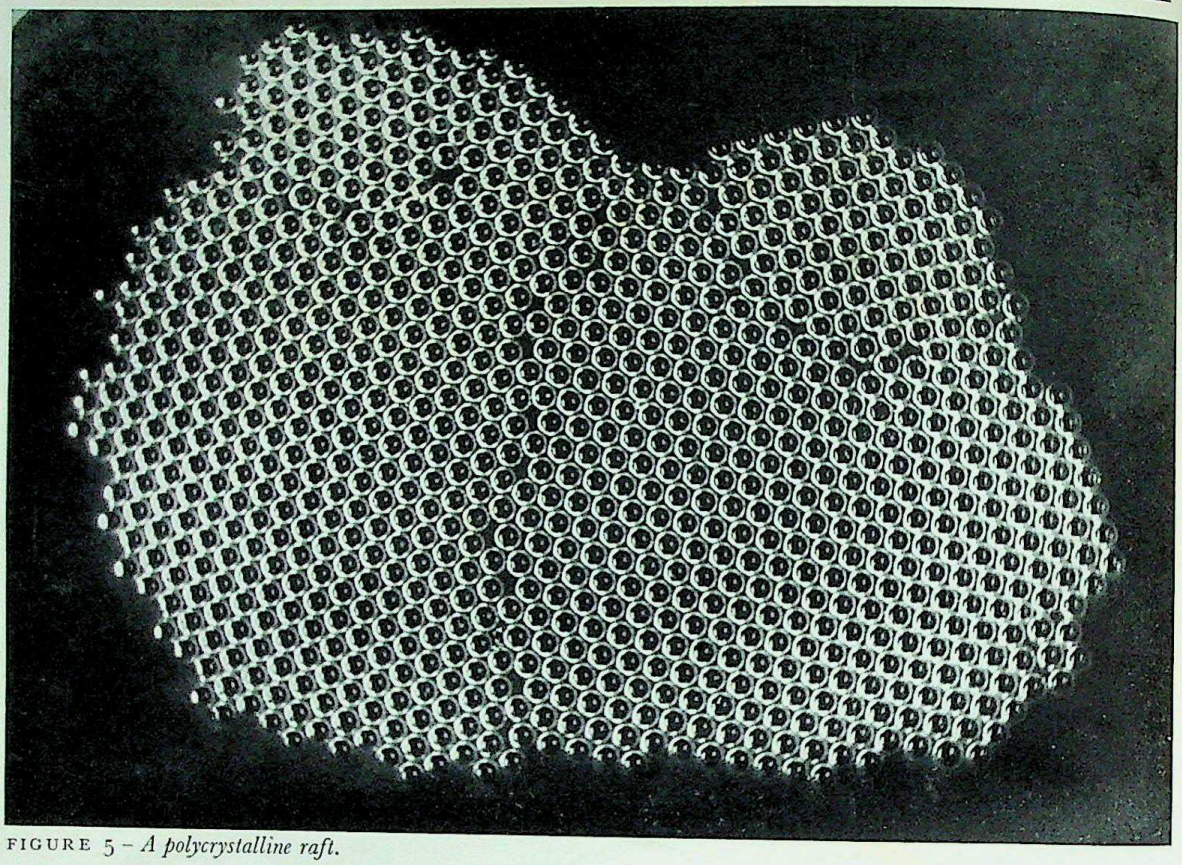


FIGURE 5 – *A polycrystalline raft.*

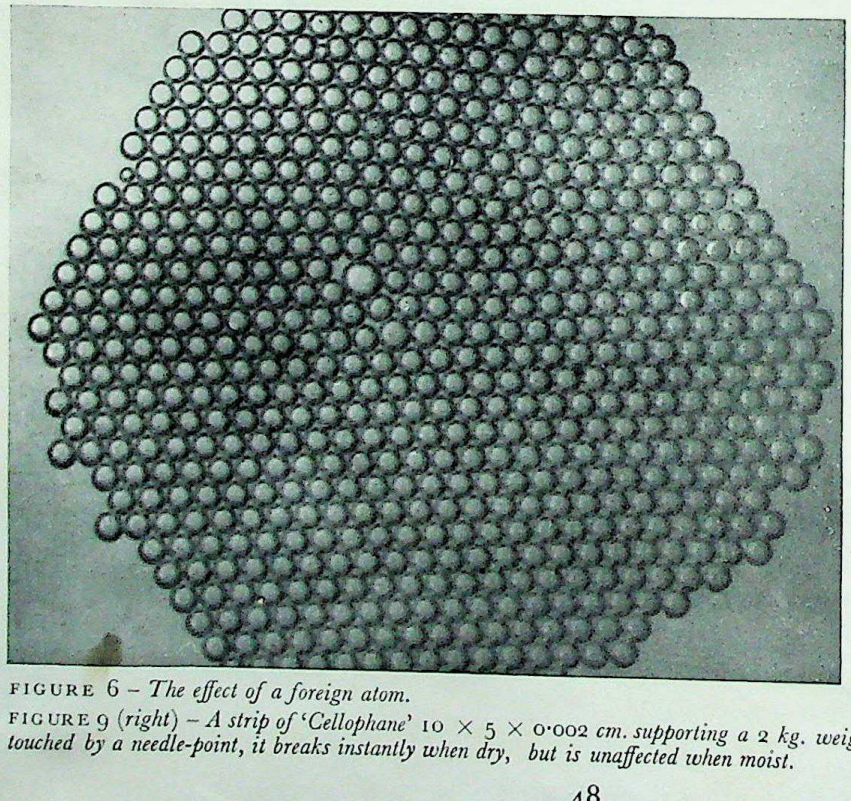


FIGURE 6 – *The effect of a foreign atom.*

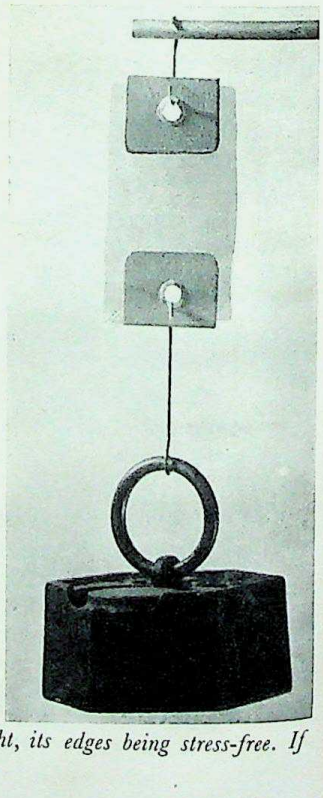


FIGURE 9 (*right*) – *A strip of 'Cellophane' 10 × 5 × 0·002 cm. supporting a 2 kg. weight, its edges being stress-free. If touched by a needle-point, it breaks instantly when dry, but is unaffected when moist.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

When, however, there are a number of crystals in the metal which are variously orientated with respect to each other, the atoms at the boundaries must somehow adjust themselves so as to make the best of both worlds. Figure 5 shows a raft composed of four such 'crystals,' and it is interesting to see the way the boundary is marked out by a series of dislocations or misfits. The structure of each crystal can be seen right up to the boundary, but it is slightly distorted by the necessary adjustment of the atomic positions at the boundaries. We can see that a simple slip process is confined to one crystal only; it cannot continue into the next, when a fresh start must be made. Figure 6 illustrates another feature which is exceedingly important in metallic structure. A few bubbles of different size have been deliberately introduced to represent atoms of impurity in the metal. They spoil the regular structure in a remarkable way, upsetting the rows for a considerable distance. We see here an explanation of the very large influence of small amounts of impurity on the mechanical and other properties of a metal. Each atom of impurity affects a large volume all round it because it throws the regular rows out of their stride.

Another feature well shown by the model is the power of the metallic structure to recover from distortion. It has an indestructible crystallizing power: it cannot stay in an amorphous or irregular condition. The raft can be crushed by moving one spring towards the other. Slips take place along rows in directions making 120° with each other, but the bubbles always adjust themselves so that the raft remains crystalline. By moving the springs slowly apart again, we can 'draw out' the raft, and again the bubbles slip and move so that new rows appear between the springs and we are left with a regular crystal as before.

(4) THE STRENGTH OF A METAL

A single perfect crystal of a metal is extremely weak, gliding along its slip planes with hardly any resistance. If, however, it is cold-worked, the perfection of the structure is destroyed. Different parts are orientated differently, and many dislocations like those illustrated by figure 5 must be created. At the same time it becomes stronger, so the strength must in some way be dependent upon the distortion of the structure. We can use the analogy of the model to show how this comes about, and even to calculate in a rough way an estimate of its strength which is in approximate accord with that measured experimentally.

Figure 7 shows typical measurements of stress and strain made with a test piece of polycrystalline pure iron by Smith and Wood. As the tension is applied to the specimen, at first it yields elastically as shown by the lower curve, and if the tension is released it recovers its original length. Beyond a certain point, about 8 tons to the square inch in this case, it yields. It is pulled out by the tension, and does not recover if the tension is released. The yield is very large compared with the elastic extension, so the strains for the upper curve showing the yield are plotted on a scale reduced a hundredfold. In yielding, it is distorted and hardens, so being enabled to withstand the greater strain, until finally at about 18 tons to the square inch it breaks. The yield-point, as we have seen, is greatly influenced by the previous history of the metal. Yield occurs at a low stress if the metal is well annealed and at a high stress if it has previously been cold-worked. The coefficient of elasticity, which defines the ratio of stress to strain, is, on the other hand, almost independent of the state of the metal, and is only slightly affected by impurities. In other words, all samples of iron follow at first the same curve in figure 7 within their elastic range, but may break away from it at very different points. This distinction is important. To define stress and strain, we may picture a cube of the material of unit dimensions on each edge. The shear stress is the tangential force on opposite faces tending to slant it over, the shear strain is the angle it is slanted through in consequence. The coefficient of elasticity is the ratio of stress to strain.

A possible clue to the factors which determine

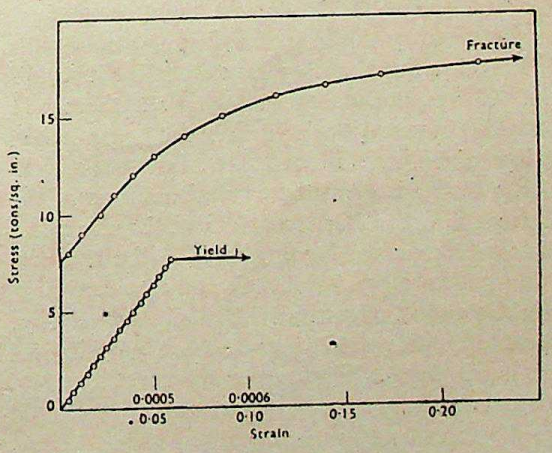


FIGURE 7 – *The stress-strain curve for pure iron.* (*S. L. Smith and W. A. Wood*, Proc. Roy. Soc., *May* 1941.)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

the point at which a metal ceases to stretch elastically, and begins to yield, is afforded by figure 4. The little raft of bubbles shears elastically until its top edge has moved on by about one bubble width as compared with the bottom edge; the stress is then released by a slip of one row of bubbles over the other. It must obviously wait until it is sheared about this amount before it is worth while slipping, so to speak, because if it slipped when it had only moved on a fraction of a bubble width it would end up with a greater strain in the opposite direction. If s is the width of a bubble and t the breadth of the raft, the shear strain builds up to an amount about s/t before slip takes place.

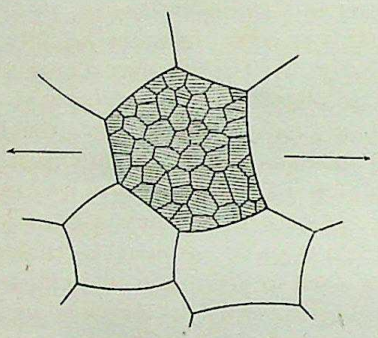


FIGURE 8 – *A diagrammatic representation of the fragmentation of a metal crystal by cold work.* (Nature, 1942, **149**, 511.)

Now picture our metal as built up of a number of differently orientated units as in figure 8, of average size t. Each bit must slip independently, and the smallest jump which can take place is the distance s between nearest atoms, like the bubble width in figure 4. We should therefore expect that the metal could be strained up to an amount s/t elastically, but that beyond that point it would yield. Corresponding to the *strain* s/t, there will be a yield *stress* ns/t where n is the appropriate elastic coefficient. The distance s between neighbouring atoms is given by crystal analysis of the structure, and the elastic coefficient for shear is a well-known constant for any metal. If, therefore, we can get an estimate of t, the dimension which limits the extent of an individual slip process, we can calculate the yield stress and compare it with what is observed. The measurement of t should of course be made on the specimen whose yield we are going to measure, because, once it yields, t gets smaller and the yield-point goes up.

We can make a shot at the elusive t by means of a well-known optical principle. A highly perfect optical grating with a large number of regularly ruled lines produces very narrow or 'sharp' spectra when monochromatic light is diffracted by it. If the number of lines in the grating is reduced, the spectra become broad and diffuse, and there is a simple relationship between the number of lines and the breadth of the spectra. A corresponding phenomenon is observed with X-rays. The X-ray diffraction lines produced by a well-annealed specimen of pure metal are sharp, but when the same metal is cold-worked the X-ray lines become broad and fuzzy, owing to the breakdown of the perfect crystals and the creation of dislocations and strains. There is a limit to the amount the lines can be broadened in this way. The metal has a high power of recrystallization, and if momentarily excessively shattered it heals its wounds to a certain extent. Wood has estimated the lower limit of fragment size in several pure metals by ascribing the whole of the line-broadening to size effect, and in the following table these breadths are used to calculate their yield stresses in shear:

	s (cm.)	t (cm.)	ns/t (tons/in.^{2})
Copper ..	$2{\cdot}56 \times 10^{-8}$	$0{\cdot}7 \times 10^{-5}$	10·6
Nickel ..	$2{\cdot}49 \times 10^{-8}$	$1{\cdot}2 \times 10^{-5}$	10·3
Silver ..	$2{\cdot}88 \times 10^{-8}$	$0{\cdot}8 \times 10^{-5}$	6·7
Iron[1] ..	$2{\cdot}42 \times 10^{-8}$	$3{\cdot}2 \times 10^{-5}$	4·1

It is interesting to see that these calculations give figures of about the right amount. When one goes into the matter more closely, however, many complications appear which show that we are touching only the fringe of the problem. Different X-ray diffraction lines in a given specimen do not broaden to the same extent, as if, to put it loosely, the perfection had a different range along and across the grain. The form of the distortions in the metal is unknown, for it will be seen from the above table that they are on far too small a scale to be measured under the microscope. There is the serious objection to the above calculation, that the broadening is probably largely due to local strains in the metal caused by the cold work. Such strains cause variations in the scale of the crystal pattern from point to point, and so also make the diffracted beams diffuse. Nevertheless, it is interesting to note that if we assume that, by estimating the range of perfection by the breadth of the X-ray lines, we are also estimating the

[1]This figure is for pure iron, which is a very weak metal as compared with the carbon-containing iron to which we are accustomed.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

dimensions of the individual slips, we do get figures which are at any rate of the right magnitude.

We can now see in a qualitative way why a metal is strong, and how its strength can be increased. It is strong if each little slip process is confined to a short run in the metal and not allowed to spread over large perfect crystal grains. This restriction can be brought about by cold work and by putting foreign atoms in the metal to spoil its perfection of structure. Figure 6 illustrates the effect of atoms of impurity which distort the regular rows.

One might now ask, why not spoil the structure so much as to inhibit slip altogether, and so make it exceedingly strong? Here we come up against a curious paradox, which is really at the root of the valuable mechanical properties of the metallic state. *In order to be strong, a metal must be weak.* A body which cannot slip is brittle. When it is pulled, there is bound to be somewhere a minute crack or point of weakness, as was first pointed out by Griffiths, and at the sharp end of this crack there is an excessive strain which causes the crack to deepen; in other words, the material tears across. Brittle substances can be strong in compression because cracks do not then extend, but they will not stand being pulled. In a metal, on the other hand, just because it yields when it is pulled too hard, a crack will not deepen. The metal gives way at this point and relieves the strain. A very simple experiment which anyone can try illustrates this effect. The 'Cellophane' used for wrappings is brittle when dry, slightly plastic when moist. By gumming cardboard supports to the top and bottom of a strip of 'Cellophane,' leaving the edges free as in figure 9, so that cracks do not start from them, one can hang on it a very considerable weight. If it is pricked with a needle-point when dry it breaks instantly. If now one breathes on the 'Cellophane,' the needle-prick has no effect. The 'Cellophane' flows enough around the pricked point to stop the spreading of a crack. I am obliged to Dr Orowan for this illustration[1].

Here is another one of a more homely character. A smile is ordinarily quite a pleasant movement, but we all know how painful it can be when the strain is concentrated at one point due to the rigidity associated with a cracked lip.

[1]Note that for this experiment to succeed when the air is moist the 'Cellophane' sheet must first be artificially dried.

(5) SUMMARY

At the beginning of this article, the peculiar metallic attribute which makes metals an essential basis for tools, machines, and structures was defined as a combination of strength and rigidity with toughness. We can now see how this peculiar combination of opposed qualities is brought about. The metal parts of a machine may give elastically, but they must not yield in the sense of becoming permanently deformed by the strains ordinarily placed upon them. Yet they must always hold this power of yielding in reserve, so to speak, if the metal is to retain its other precious property of reliability. As Griffiths has shown, thin fibres of glass or silica can be as strong as steel if they are fresh and have no cracks, but a touch on their surfaces makes them snap instantly under a strain. Though glass is harder than steel we cannot build our machines of it, for any sudden jar would smash them to pieces. A metal is reliable because it knows when to yield, and in yielding becomes even stronger. The art of compounding and heat-treating a metal to fit it for various mechanical tasks is a matter of nice compromise. We harden it by forging and hammering and mixing a metal with other metals, or putting carbon in iron, and go just as far as we dare while still preserving its ultimate power of yielding slightly under excessive strain. The peculiar atomic structure of a metal, the way the atoms can move past each other without breaking bonds, the way in which their relative positions can be altered by heat-treatment in the solid state, these are the qualities which make it so ideal a material for technology. We have only begun to explore the possibilities of creating new alloys with still more desirable properties. In the past great advances have been made in the metallurgical art by trying out various new combinations and discarding those which showed no improvement. The more we can pry into the fundamental factors which determine strength, the better the prospect of advancing more directly towards our goal and achieving even more spectacular successes in this age of metals.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The Royal Society of London

Part II

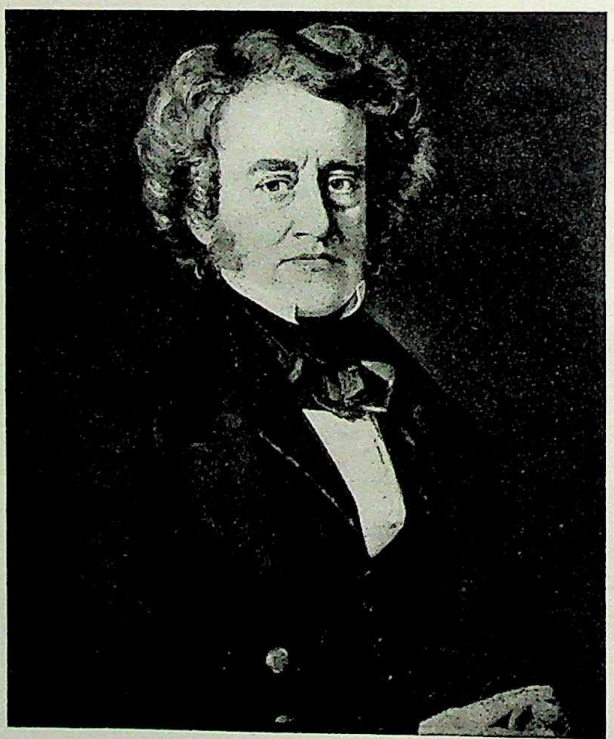
COLONEL SIR HENRY LYONS

In the second part of his account of the fortunes of the Royal Society, Sir Henry Lyons carries the story from 1820 to the present time. He shows that, as soon as scientific Fellows came to form a majority in the Council, the Society's influence on science rapidly grew, until now it is able to give powerful and beneficent help to the advancement of scientific knowledge.

In June 1820, shortly after the death of Sir Joseph Banks, the Council elected Dr W. H. Wollaston, the eminent chemist, to be President until the next Anniversary Meeting. He therefore presided at the Council meetings during the autumn, and certainly influenced the choice of members for the new Council, in which twelve out of the twenty-one were men of science; Sir Humphry Davy was nominated as President. It was a notable change of policy for the scientific Fellows to be in the majority, and Davy continued the practice, so that the councillors who were men of science varied from twelve to nineteen. Davy resigned, from ill health, in 1827 and was succeeded by Davies Gilbert, who strongly opposed all kinds of reform. His successor was H.R.H. the Duke of Sussex, the sixth son of King George III, whose election in 1830 was hotly opposed by many of the scientific Fellows, J. F. Herschel being put forward as an alternative candidate.

The Duke, however, was elected by a small majority and at once rendered the Society one important service: at the first meeting of Council at which he presided he proposed that the Treasurer's Report for 1829-30 should be printed and circulated to all the Fellows. This was done, and for the first time the Fellows were fully informed of the financial position of the Society, what sums had been received, and how their funds were being expended. Similar information has been given annually to the Fellows ever since, though it had not previously been available to any but members of Council. The misgivings of the scientific Fellows who were pressing for reforms were amply justified, and their criticisms could now be supported by irrefutable evidence.

The Council as now constituted became a much more active body than it had been in the past and the average attendance of its members rose at once. The Duke of Sussex was succeeded by Lord Northampton, an active geologist who had been for two years President of the Geological Society. Under his guidance the Council began to prepare plans for the reorganization of the Society, and in 1846 appointed a 'Charters Committee' with instructions to report what revision of the Charters was desirable, with a view to obtaining a supplementary Charter from the Crown. The Committee consisted of the President, the Vice-presidents and the Secretaries, to whom W. R. Grove, an



Sir John Herschel.
(By courtesy of the Royal Society.)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

eminent mathematician and a lawyer of wide experience, was added.

After a careful study of the whole matter the Committee reported that no revision of the Charters was necessary, since the objects desired could be attained by a revision of some of the statutes, and to do this was within the powers of the Council. It had the additional advantage that necessary changes could be made without bringing the whole matter before a general meeting of the Fellows, at which those who were opposed to any reform would probably organize an active opposition. The Committee therefore proposed that: (1) the election of Fellows should take place on the third Thursday in June; (2) that the number recommended by the Council for election in each year should not exceed fifteen; and (3) that the names of all candidates proposed should be printed and circulated to all the Fellows in the first week in May.

In this way the right under the Charter of the Fellows as a body to elect as many as, and whomever, they pleased was not interfered with; but in practice the Anniversary Meeting has always accepted the names recommended by the Council. Previously, from twenty-five to thirty candidates —and occasionally as many as forty or fifty—had been elected annually, so the new procedure soon brought about a reduction in the number of Fellows, which had for many years been recognized as desirable. The fifteen candidates were selected by the members of Council, who were now almost all men of science, and this ensured that their qualifications were such as were needed to raise the scientific reputation of the Society.

The Committee, as well as the Finance Committee, reported on the effect that the proposed statutes might have on the income of the Society, and both reported that with due care the normal expenditure could be met. The new statutes were therefore approved by the Council on 10th February, 1847, and the first batch of fifteen candidates recommended for election was approved by a General Meeting of the Fellows in June 1848. Ten years later a Committee appointed to report on the working of the revised statutes recommended that the new procedure should be continued, as it had proved to be quite satisfactory.

In 1847 the number of Fellows was 764; by the end of 1860 it had fallen to 630, of whom 330 were scientific men, so that now for the first time these formed a majority in the Society.

There was much to be done to make the administration adequate to the new requirements. Much of the procedure hitherto in use needed revision. Particularly the increasing number of scientific Fellows, and the rapid growth of all branches of science at this time, resulted in a large increase in the number of scientific communications to be examined, and if accepted to be published in the *Philosophical Transactions* or the *Proceedings*. By 1860 much had been accomplished, and the Council, which now contained an average of nineteen men of science out of its twenty-one Councillors, was administering a Society mainly composed of scientists, and wholly devoted to the improvement of natural science. The aims of its founders were now well on the way to being fulfilled.

In 1861 General Sabine, the magnetician, was elected President; he held the position for ten years. By this time the Councils had come to the conclusion that a long tenure of the presidency was not in the Society's best interests; also, as the holders were now being selected from Fellows distinguished for their scientific work, it was difficult for them to devote their time to its needs for long periods. Sabine was succeeded by Sir Joseph Hooker, who stipulated that he should not be expected to hold the Presidency for more than five years, since his work at the Royal Gardens, Kew, was increasing. Such a period had already been suggested at the Council, and has subsequently been recognized as the limit of a President's tenure of office. No special restrictions were suggested for the other offices, and two of the Secretaries and two Treasurers held their posts for twenty years or more. There may have been good reasons for this at the time when many changes were being introduced, but in recent years their periods of office have been limited to ten years.

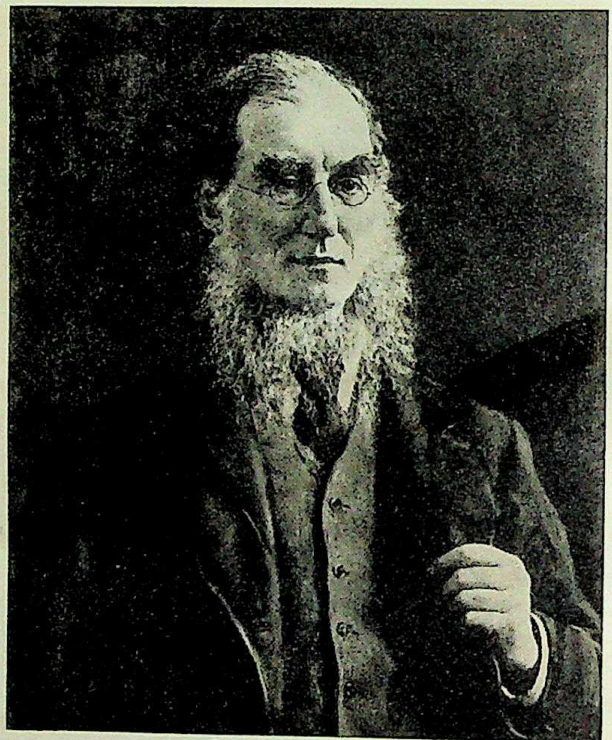
By 1857 the invested capital of the Society amounted to £30,000, but the amount received from annual subscriptions as the number of Fellows diminished became less, while the cost of printing and publishing the constantly growing number of important scientific communications in the *Philosophical Transactions* and the *Proceedings* was mounting. The financial position would have become difficult had not the extension of London westwards greatly increased the value of land in the village of Acton, where the Society owned about 35 acres. In 1880 the Council received an offer to purchase this land for about £32,000 and accepted it, thereby easing the financial position. By the end of the century

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

the value of the investments held for the General Fund was £81,000, while those of the Medal and Lecture Funds amounted to £46,000, received from a number of bequests. Dr Wollaston had started the Donation Fund in 1828 with the object of the income being used to advance scientific research. Since then other bequests for a similar purpose have been received, and the capital now amounts to £40,000. By 1900 the Society was therefore free from financial anxieties, and was in a position to assist research workers of merit by grants up to a total amount of £1,100 annually.

The work of the Council, both scientific and administrative, was now increasing rapidly, so much so that it was becoming more than the Council and the standing committees for Finance, Library, and Scientific Relief could deal with. The number of standing committees was therefore increased until, by the end of the century, there were twenty of them. A special group of eight scientific or sectional committees was appointed in 1896, and these greatly relieved the scientific work of the Council.



Sir Joseph Hooker.
(By courtesy of the Royal Society.)

The Society has always maintained close relations with men of science in other countries. In 1742 it arranged to compare a yard measure and a pound weight with the corresponding measures in use in France, and sets of each were provided respectively for the Society and for the Académie des Sciences, Paris. In 1787, and again in 1821, the Society co-operated with French geodesists in carrying out with all the accuracy then attainable triangulation between the observatories of Greenwich and Paris. In 1836 von Humboldt wrote to the Duke of Sussex, then President of the Society, to seek his support in establishing stations for the study of terrestrial magnetism in England and her overseas possessions, and this he was able to arrange. From time to time representatives of Great Britain, usually nominated by the Society, served on other international scientific commissions.

In 1894 the Royal Society of Göttingen invited the Royal Society to send a representative to a conference at Innsbruck where gravitational observations would be discussed. This proposal was accepted, and led to another, made in 1898, that the Society should be represented at a meeting of the academies and scientific societies of Göttingen, Leipzig, Vienna, and Munich. The Council accepted the invitation and instructed their delegates that, regarding the question of the Royal Society's adhesion to a proposed Association of Academies, it should be made clear that such adhesion must be contingent on the Association becoming truly international by including other countries, especially France. This was agreed to, and the Royal Society was desired to ascertain the views of the Academies of Science at Paris and St. Petersburg, and of the Accademia dei Lincei at Rome. All expressed support for the proposal, and the International Association of Academies was formed. It was active for fourteen years but came to an end on the outbreak of war in 1914.

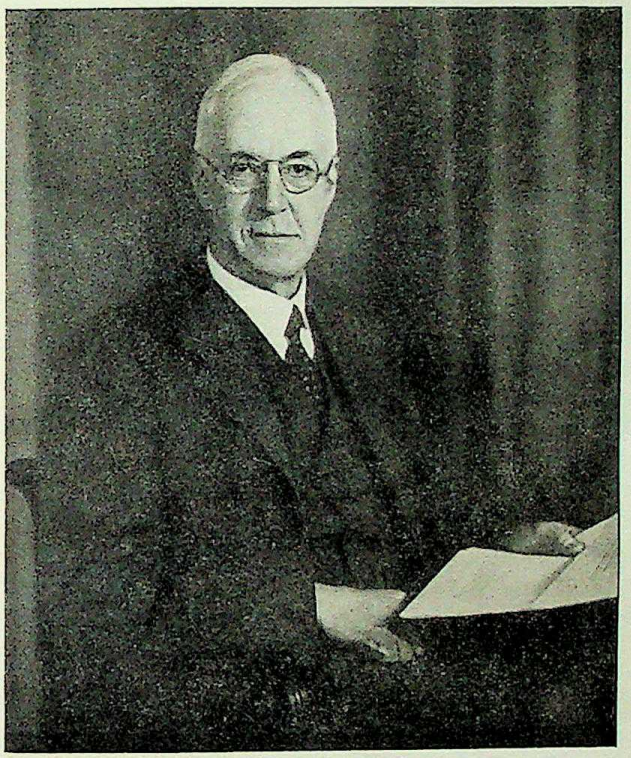
In 1857 the Society undertook the preparation of a Catalogue of Scientific Papers published after 1800. The cost of compilation was met from the Society's own funds, but the Government met the cost of printing and publication. The experience gained by 1900 showed that the cost of a similar publication for the next century was greater than could be borne by any private institution; it was therefore proposed to carry out the work by international co-operation. The matter was discussed by the delegates of a number of countries and it was agreed that the scheme put forward should be tried for five years: the Society agreed to take charge of the work and advanced the capital necessary for

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

printing, etc. So successful was the result that the scheme was continued for two more five-year periods; by then, however, the war of 1914-18 had broken out and publication had to be discontinued. In 1919 the international council met to review the situation and decided that publication should not be resumed; and in 1922 the executive committee asked the Society to allow the Treasurer to act as receiver and to wind up the undertaking. This was a lengthy business and was not completed until 1935 when, on the advice of the Society's chartered accountants, about £13,000 due to the Society was written off by the order of the Council.

In earlier times the amount of information which was given to the Fellows about the administration of the Society was very small, but in 1896 the Council decided that a volume should be published early in each year providing information on the membership and the Society's various activities. This year-book has since been published regularly in January of each year. In 1898 certain information which had been collected for the year-book but which changed rarely if at all, such as the texts of the Charters, was collected to form the *Record of the Royal Society*. This is published only occasionally, the latest edition (the fourth) having appeared in 1940. It was now the policy of the Council to keep the Fellows fully informed of the changes which were made from time to time in the administration, and if desirable to consult them—though the right of the Council to make laws and statutes on its own authority as given in the Charter remained. In 1915 the Council decided to circulate its *Report to the Society*, which is presented at the Anniversary Meeting to all the Fellows, and to discuss it at a special general meeting early in November; here it could be explained and suggestions considered. In 1916 the Council ordered that the list of candidates for the Fellowship should be laid before the sectional committees, at which the qualifications of candidates could be discussed. In 1918 it was ordered that before any new statute or any modification of an existing statute was approved it should be brought before a special meeting of the Society. In 1935 the Council decided that the annual reports of the research professors, Fellows and students who had been appointed by the Council, and whose expenses were met from any of the Society's research funds, should be added to the Council's report. In these ways, and by the publication of *Notes and Records of the Royal Society* once or twice annually, a considerable amount of information is now being made available to the Fellows regularly.



Sir Henry Dale.
(Present President of the Royal Society.)

In 1919 and some of the following years the Society received very considerable gifts or bequests, the income from which is to be devoted to research in some branch of science. By these gifts the total invested capital of the research funds had been increased by 1939 to about £550,000. With the income so derived the Society has been able to appoint some fifteen to eighteen research professors, Fellows, and students who can devote the greater part of their time to some branch of research approved by the Council.

When we see the great improvements which have been made in the administration of the Society, and the notable advances in science due to the efforts of its Fellows in the ninety-six years which have passed since the statutes were revised in 1847, we may confidently expect that even greater and more important advances will be achieved by their successors in the years which lie ahead.

सन्दर्भ ग्रन्थ
REFERENCE BOOK
यह पुस्तक वितरित न की जाय
NOT TO BE ISSUED
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Locust invasions and their control

A. D. IMMS

In many parts of Africa and Asia locusts are still the menace to crops that they have been since the dawn of history. In recent years, scientific methods have been applied to the study of these predatory insects and their mass migrations, and there is now good reason to hope for an effective counter-offensive.

Locusts belong to the family Acrididae which comprises the common or short-horned grasshoppers (figure 1). Several thousand species of Acrididae are known, but fortunately only a small number comes into the category of locusts. A locust may be defined as a species of short-horned grasshopper (figure 7), which, at times, becomes predominantly gregarious and migrates considerable distances in great swarms. The depredations of these insects have menaced the food supply of man ever since he adopted agriculture (figure 5). References to locusts and their activities occur in the writings of Pliny, and in many Chinese, Egyptian, and Greek texts, besides the familiar Biblical allusions. The earliest discovered record of these insects is stated to be a representation of a locust on the wall of an Egyptian tomb, dated about 2400 B.C.

The life-cycle of a locust is as follows. The eggs are deposited by the female below the soil in 'pods' or packets. In countries with a cold winter the eggs remain dormant throughout this season until the spring, when the young insects or 'hoppers' emerge. In the tropics they hatch within a few weeks of being laid, provided there is sufficient moisture. The difference between grasshoppers and locusts first becomes evident in the hopper stage: with the former the individuals are solitary or, in other words, each lives independently of the others, whereas in the latter they congregate in dense bands (figure 4). Further development consists in rapid growth, together with periodic moulting of the skin, which occurs four to six times before the adult insect appears. The whole cycle lasts for about a year in temperate climates, but in the tropics there may be two or three generations in a year. Locust hoppers betray mass movements in bands that may be spread over several square miles. Eating all in front of them, these hordes of individuals move relentlessly forward irrespective of obstacles. An impelling force urges this movement; it is not hunger, since they often leave a fertile zone to enter an arid one. Recent research has proved that these movements are dependent upon temperature and occur only when it is sufficiently high, while excessive heat, like too low a temperature, checks them. The winged adults, like the hoppers from which they have been transformed, also betray mass movements, since they take to the wing in vast swarms. These similarly are impelled into such activity by causes other than mere lack of food.

Two main phenomena have long stood in the way of a solution of the locust problem. First, the more or less irregular periodicity of the outbreaks: they are not annual events but recur in cycles of several years (figure 8). Anti-locust measures are speedily organized and their application may alleviate pressing needs, but they are usually applied too late, besides leaving the menace of subsequent swarms uncatered for. The second is that swarms may arise in one country and cause depredation in numerous other lands along their paths. Yet, however effective the measures taken in these individual countries may be, they have no bearing on the general situation, viz. the source of origin of the swarms. To quote one example, swarms of the Desert Locust commonly arise in India during the summer monsoon rains, and migrate to Persia and Arabia, where their progeny give rise to further swarms that may pass on to Soviet Asia, Palestine, Iraq, Egypt, and East Africa. Lack of fundamental knowledge, and of a guiding policy for anti-locust measures founded upon it, have, therefore, from time immemorial frustrated human efforts to cope with the menace (figure 6).

In 1921 B. P. Uvarov, of the Imperial Bureau of Entomology in London, advanced what has subsequently become known as the phase theory of locusts. Subsequent observations made in South Africa in 1932, both in the laboratory and in the field, by J. C. Faure, and by other workers elsewhere, have so fully corroborated the main

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

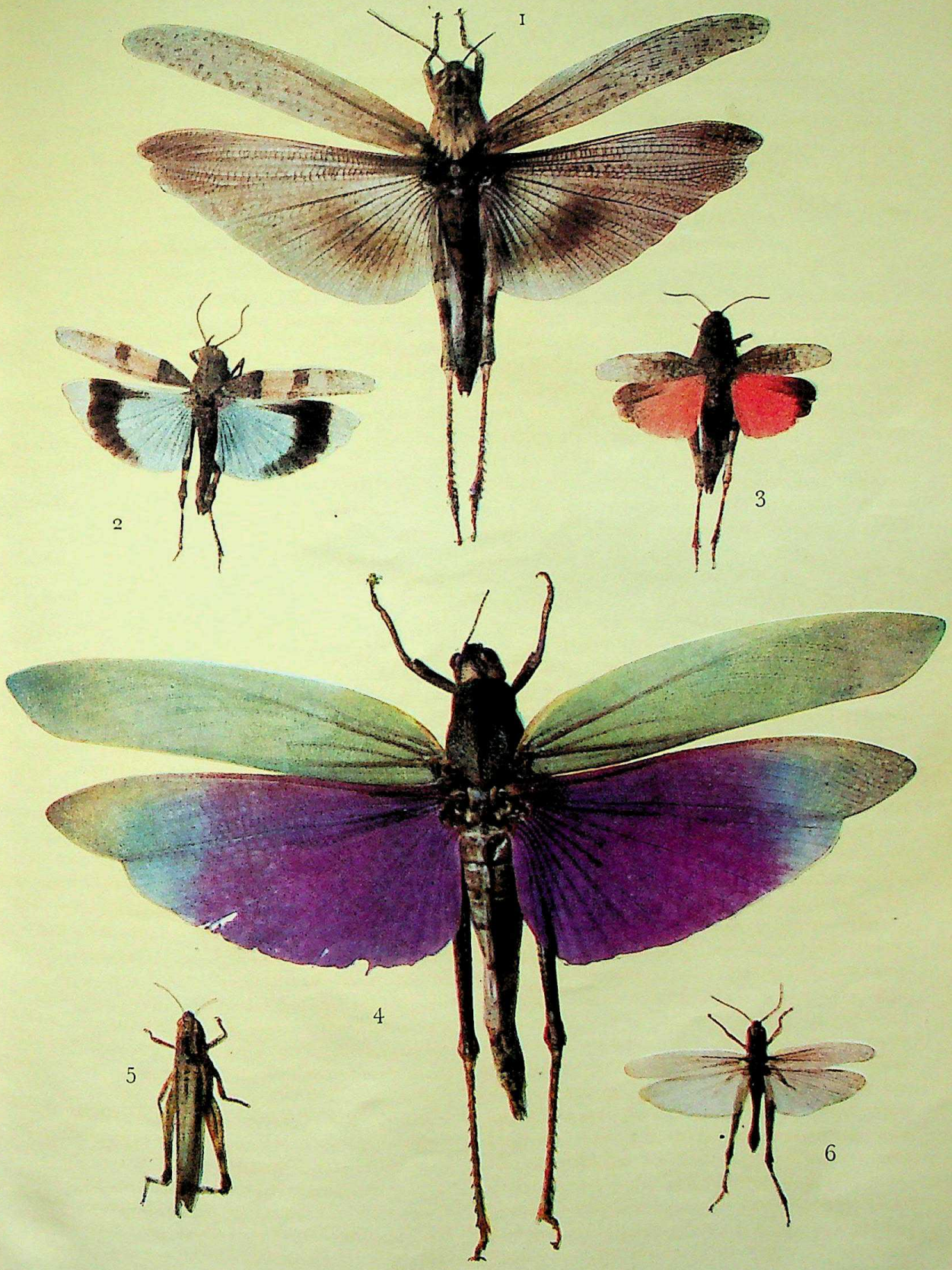
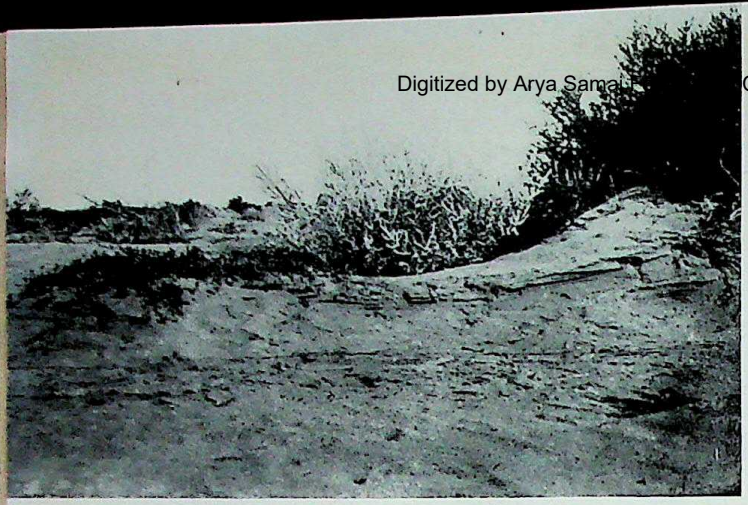
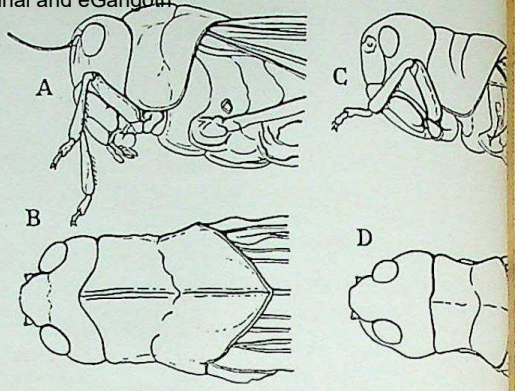


FIGURE 1 – *Acrididae or short-horned grasshoppers (actual size).* 1, Anacridium aegyptium, *Southern France.* 2, Oedipoda coelurescens, *Savoy.* 3, Psophus stridulus, *Tirol.* 4, Titanacris albipes, *Amazons.* 5, 6, Mecostethus grossus, *the largest English short-horned grasshopper.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri





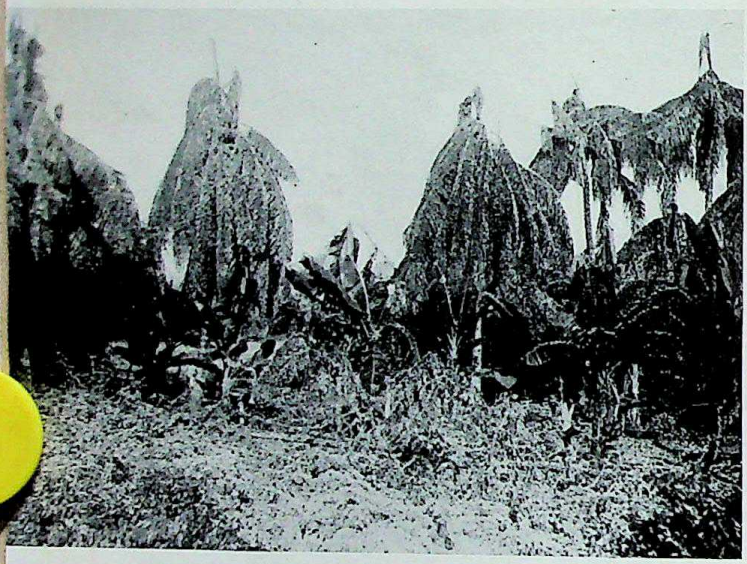


FIGURE 2 (*top left*) – *Showing the type of country f an outbreak area of the Desert Locust on the Red S of the Sudan.*

FIGURE 3 (*above*) – *Form of thorax in the African Mi Locust.* A, B, *in the solitary phase;* C, D, *in the grega migratory phase.*

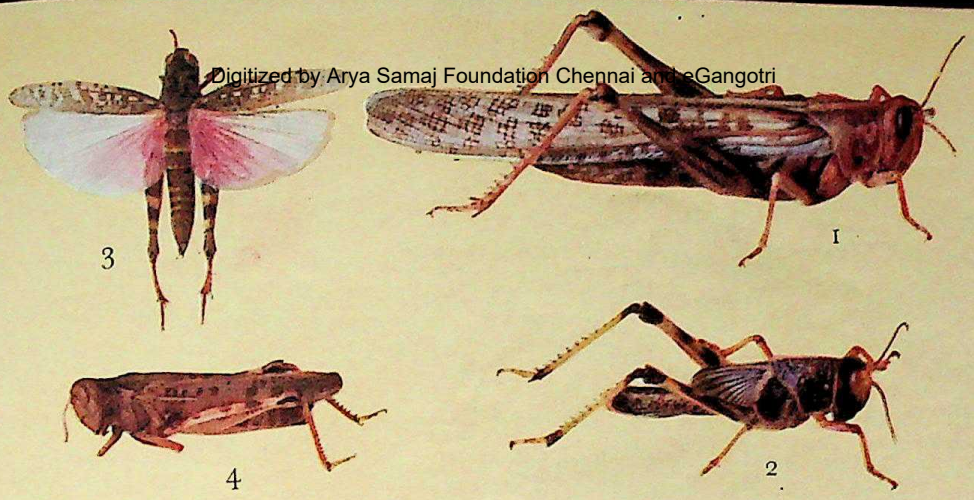
FIGURE 4 (*left*) – *Coco-nut leaves breaking un weight of locusts settling on them: near Cebu, Phi Islands.*

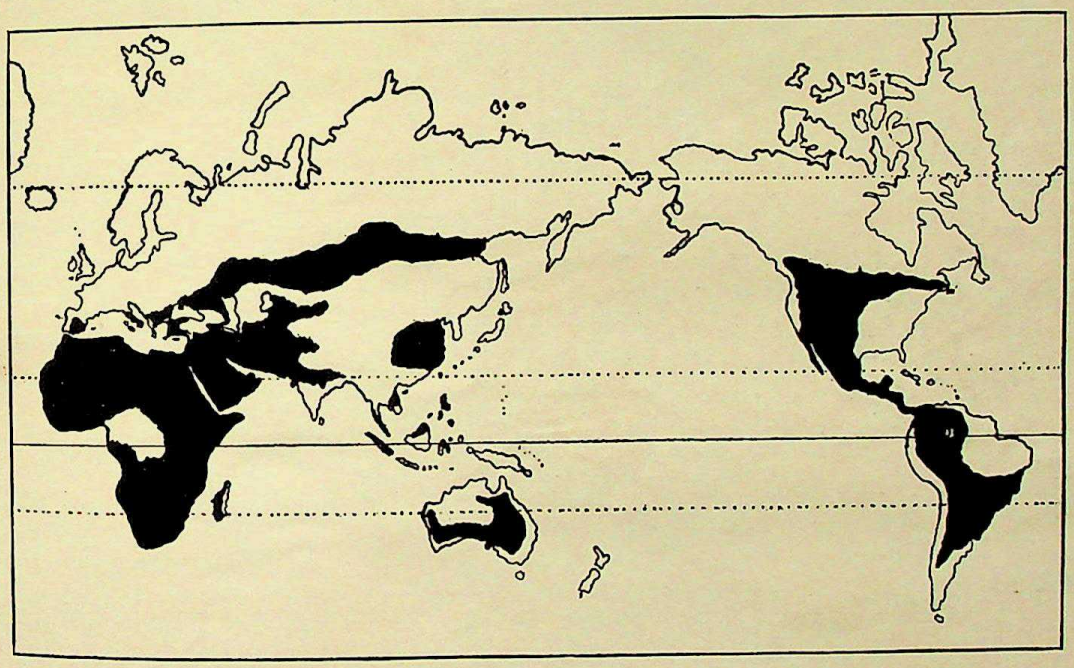
FIGURE 6 (*below*) – *A locust swarm: on the bor Kenya and Uganda.*

FIGURE 5 – *Hoppers of the Moroccan Locust on wheat: Caucasus.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri





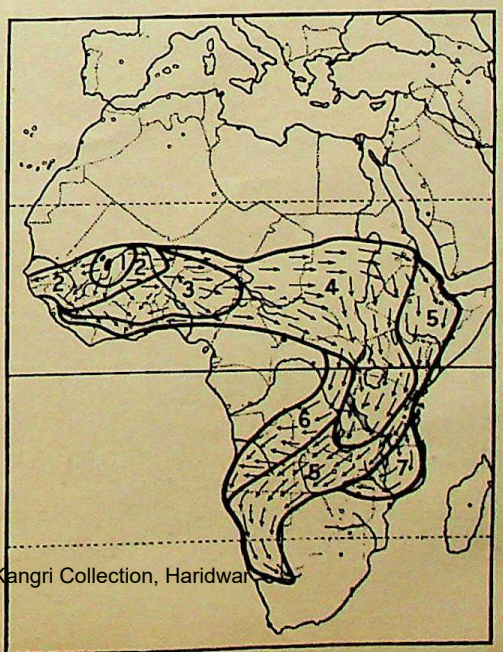


FIGURE 7 (*top*) – *Typical locusts* (*actual size*). 1, *Desert Locust* (Schistocerca gregaria), *winged adult.* 2, *Hopper of same, showing developing wings.* 3, *Italian Locust* (Calliptamus italicus): *Southern France.* 4, *Moroccan Locust* (Dociostaurus maroccanus): *Smyrna.*

FIGURE 8 (*middle*) – *Areas of the world subject to invasion by locusts and injurious grasshoppers shown in black.*

FIGURE 9 (*right*) – *Spread of the African Migratory Locust from where the outbreak originated in* 1928 *in areas marked by two spots in Zone* 1 *which was invaded in the first year. Zones* 2, 3, 4, *etc., represent the spread of the invasion in successive years up to* 1934. *Arrows indicate the main directions of the invasion.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

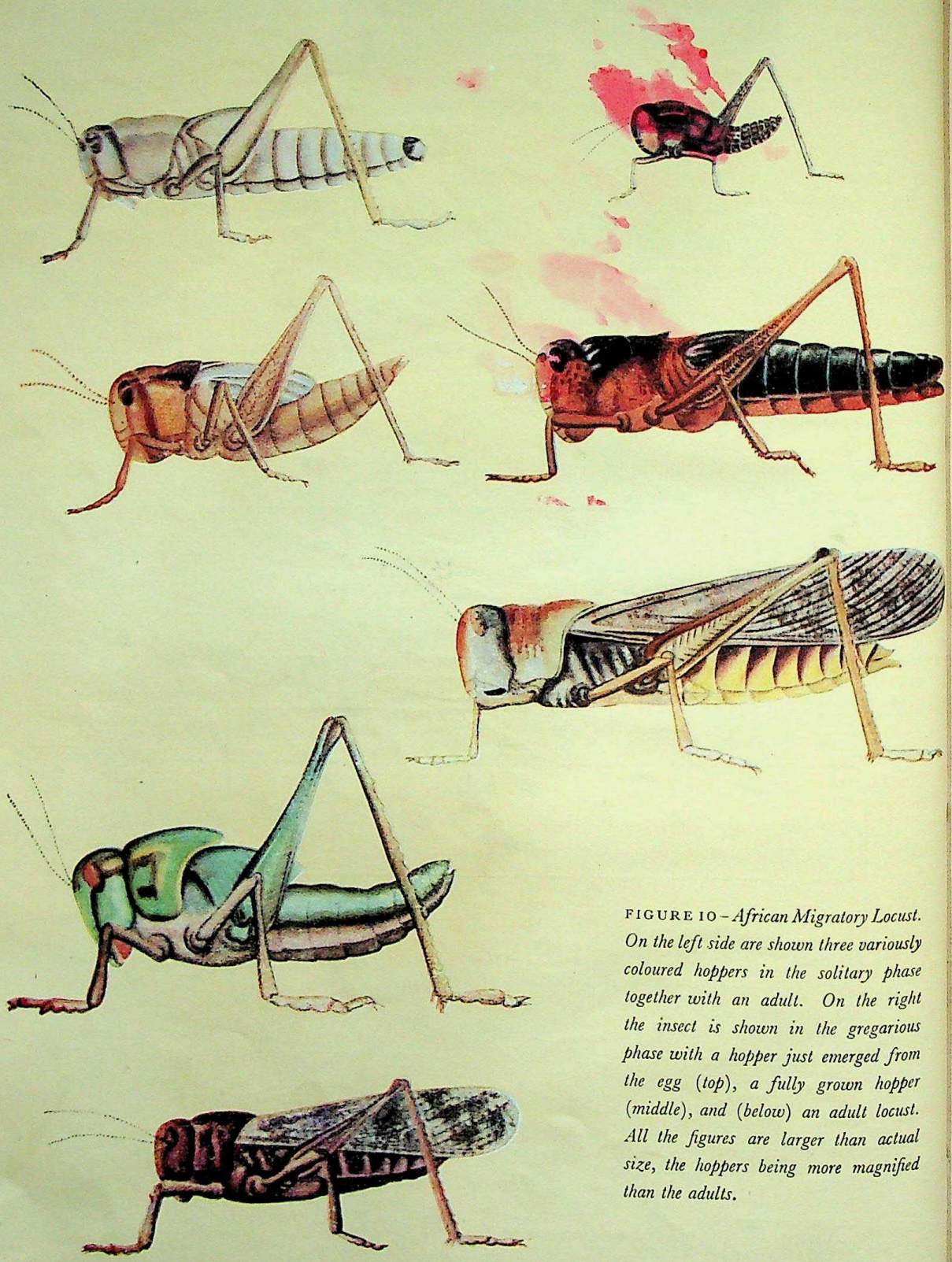


FIGURE 10 – *African Migratory Locust. On the left side are shown three variously coloured hoppers in the solitary phase together with an adult. On the right the insect is shown in the gregarious phase with a hopper just emerged from the egg (top), a fully grown hopper (middle), and (below) an adult locust. All the figures are larger than actual size, the hoppers being more magnified than the adults.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

contentions of Uvarov that his phase theory is regarded today as an established biological phenomenon. The starting-point of the theory is that a locust can exist in three biological phases, viz. a solitary one (*phasis solitaria*), a gregarious or migratory one (*phasis gregaria*), and a transitional one (*phasis transiens*). Taking the African Migratory Locust (*Locusta migratoria migratorioides*) (figure 10) as an example, the *phasis gregaria* in its hopper stages is constantly coloured black and deep orange-yellow. The adults have a short, constricted pronotum (figure 3 C, D), and the ratio of the length of the fore wing to that of the hind femur is equal to or greater than 2. In the *phasis solitaria* the hoppers are variably coloured and tend to simulate the hue of their immediate background. The adults have a longer and broader pronotum with a dorsal keel (figure 3 A, B), and the wing/femur ratio is always less than 2. The *phasis transiens* is not represented by any definite form, but is intermediate in its characters between the other two phases.

By varying the conditions, locusts can be reared experimentally from the eggs in such a way as to develop into whichever of the phases is desired. If a large batch of hoppers be reared under crowded conditions in a single cage they become extremely active and develop into a close approximation to the gregarious phase. Under less crowded conditions they display the *phasis transiens*, while individuals reared in separate containers grow into the solitary phase, the hoppers taking on the general colour of their surroundings. The great activity and consequent high metabolism of the gregarious individuals lead to the differences separating them from those in the solitary phase.

The periodicity of locust outbreaks is now known to be connected with the transformation of these insects from the harmless solitary phase into the destructive migratory one. This transformation occurs in certain localized areas, known as *outbreak areas*, which have special conditions of climate and vegetation for each locust species. It is here that the great swarms develop. In the African Migratory Locust, swarms that arose about 1928, in a restricted area of the Middle Niger in the French Sudan, were the cause of an invasion involving a great part of Africa (figure 9). Some of the outbreak areas of the Desert Locust (*Schistocerca gregaria*) have been located in lands bordering the Red Sea (figure 2), while swarms of the Moroccan Locust (*Dociostaurus maroccanus*) develop on stony hillsides where vegetation is rather scanty. The extensive movements of locust swarms make it futile for each country to attempt its own isolated control measures; failure to repress these plagues has actually been due to isolationist policy. In 1928 a severe outbreak of the Desert Locust was the moving factor in causing the British Government to take steps towards coping with the problem by setting up a special research organization. This purely British venture led to the first International Locust Conference being held in Rome in 1930 (the fifth Conference was held in Brussels in 1938). This body requested the British organization to act as an international centre for collecting information and formulating research procedure. Today a special Anti-locust Research Centre in London operates under the supervision of Sir Guy Marshall, F.R.S., with Dr B. P. Uvarov as its technical organizer. Concerted investigations by parties of British, Belgian, French, South African, Egyptian, and Indian experts have collected a vast number of field data. Under great difficulties, the outbreak centres of locusts are being located and kept under observation—often in remote and inhospitable territories. By this means any tendency towards swarming can be noted and, at the same time, lands likely to be affected can be forewarned and so be in a position to apply timely measures. Ultimately, developing swarms may be destroyed in these centres, or the ecological conditions prevailing there may be altered by cultivation or other means so that they no longer give rise to locust swarms.

[Indebtedness for the use of figure 4 is to the Bureau of Agriculture, Philippine Islands. The Anti-locust Research Centre, London, allowed the use of figures 2, 5, 8, and 9; and figures 1, 7, and 10 are from specimens in the Cambridge University Museum of Zoology.]

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

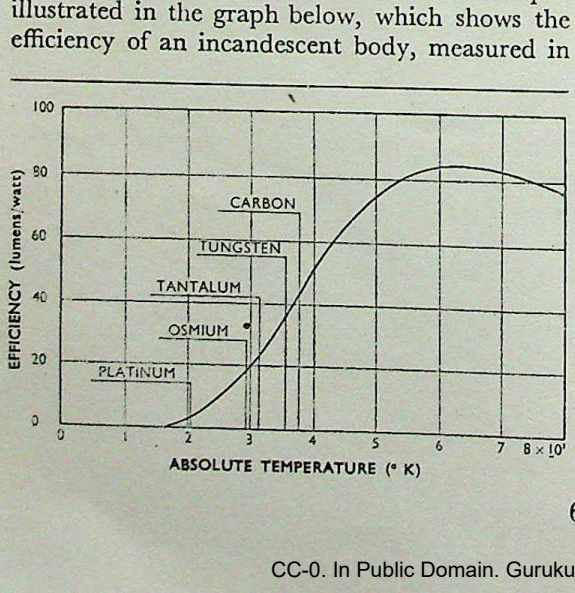
The evolution of the electric lamp

J. N. ALDINGTON

Many methods have been devised for the conversion of electrical energy into light. One of the earliest devices, namely Sir Humphry Davy's carbon arc, is still not without its usefulness, but modern scientific ingenuity has evolved a remarkably wide range of electric lamps of different kinds, adapted for every conceivable purpose. Mr Aldington describes some past achievements and outlines likely future developments.

Electrical energy can be converted into light by a variety of devices. A significant early event was Sir Humphry Davy's demonstration of the light produced by the carbon arc, which took place during a lecture at the Royal Institution early in the nineteenth century. It was not, however, until Faraday produced his electro-magnetic induction machine in 1831 that much real progress on electric lamps was possible. The development of means for readily producing electrical energy encouraged exploration of the possibilities of Davy's arc light, and it is interesting to note that carbon, used in the first experiments, is still the basis of arc lamp electrodes.

The discovery that thin wires could be heated to incandescence by the passage of an electric current led to the genesis of the first successful electric lamp of small size. As early as 1845 J. W. Starr demonstrated the production of light by the passage of an electric current through a platinum wire. Subsequent work was directed towards reducing energy losses from the filament and to the search for filament materials capable of being operated at higher temperatures than platinum. This phase of the evolution of the electric lamp is illustrated in the graph below, which shows the efficiency of an incandescent body, measured in lumens per watt, plotted against its absolute temperature. The melting-points of a number of elements which have been either suggested or used for the filaments of lamps are also indicated, although it must be appreciated that melting-point alone is not a sufficient criterion by which to judge the suitability of a filament material. For example, although carbon has the highest melting-point of any element its volatility at high temperatures greatly exceeds that of tungsten. Nevertheless, the success of carbon as the electrode of the arc lamp indicated promise of its being suitable for the filament of an incandescent lamp. Many different organic materials were carbonized in turn during repeated attempts to produce a refractory thin filament of suitably high resistance. It is no small tribute to the independent work of Swan in England and Edison in America that they eventually achieved success with such apparently unlikely materials as carbonized parchment, cotton thread, bamboo slivers, and best of all with a material not unlike the fibre of modern artificial silk (*see* figure 1).



The fact that a filament mounted in a bulb from which the air had been exhausted could be raised to incandescence more efficiently than a similar filament operating in air was appreciated about the middle of the nineteenth century. In the original work of both Swan and Edison the provision of an exhausted glass envelope enclosing the filament was further necessary because of the readiness with which carbon oxidizes when heated to incandescence in air. The skill of the glass-blower and developments in vacuum technique thus became essential elements in building the lamp industry. Such a standard of craftsmanship was established subsequent to the successful development of the carbon filament lamp announced in 1879 that very rapid progress was made (*see* figure 2, which shows different types of early carbon lamp).

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The new industry had from the first attracted scientific workers, and the success which attended their labours led gradually to the establishment, in association with the industry, of research, development, and scientific control organizations of acknowledged repute. To this fact must be attributed the remarkable advances which have been made—particularly in the last decade—in methods of light production, and the advent of new and more efficient light sources.

It was about the beginning of the present century that Von Bolton and his colleagues worked out a process by which the refractory element tantalum could be drawn into thin wire. This development enabled Siemens and Halske to announce in 1903 the successful production of low-wattage lamps using tantalum filaments and operating at higher efficiencies than carbon lamps of similar size. The comparatively long and thin tantalum filament required supporting at a number of points and the method employed is shown in figure 3, in which a tantalum lamp made in 1905 is compared with a carbon lamp of 1882 due to Lane Fox.

During the period just reviewed, many attempts had been made to prepare filaments from tungsten —the most refractory of all metals. Success was eventually achieved in 1907 by squirting through diamond dies a paste made from finely divided tungsten powder and a volatile binder. The filaments so produced were bent into hairpin shape and, after a baking process to remove the binder, were mounted in series on to a number of V-shaped supports by arc welding. The resulting structure, illustrated in figure 4, was then sealed into a glass bulb subsequently exhausted of air. In spite of the fragility of the filament structure this first tungsten lamp, operating at an efficiency twice that of the carbon lamp, enjoyed considerable success until it was displaced by lamps using drawn tungsten wire.

In 1906 Coolidge began work with a view to producing ductile tungsten. It was known that fused tungsten, unlike other pure metals such as copper or gold, was very brittle and incapable of being worked into wire. The process eventually devised by Coolidge, and known as powder metallurgy, overcame this difficulty and enabled drawn tungsten wire to be produced for the first time. In the Coolidge process, tungsten powder containing a small percentage of some additive was shaped under hydraulic pressure into rectangular bars. By the passage of an electric current these bars were then 'sintered' (i.e. the discrete particles were made to cohere without complete fusion) at a temperature of about 3,300° K in an atmosphere of hydrogen. The fragile bars of pressed powder were thus converted into metallic rods of sufficient ductility to enable them to undergo, at about 1,500° K, the shaping process known technically as 'swaging.' The swaging operation was followed by hot drawing processes, by which wire of very small diameter was eventually produced. During these operations the plastic deformation of the crystal units developed during sintering resulted in a fibrous structure of great mechanical strength. The photomicrographs in figure 5, taken at a magnification of 500, illustrate the structure of sintered tungsten compared with that of the swaged bar and drawn wire.

A notable advance was made when Langmuir demonstrated in 1913 that the blackening of vacuum lamps was due to normal evaporation of the tungsten filament. He therefore suggested the use of an inert gas atmosphere in the bulb to reduce the rate of evaporation and to allow the filament to be operated at an increased efficiency. He showed that by using a coiled filament in place of a straight wire, the loss of energy occasioned by convection and conduction could be not only reduced but more than counterbalanced by the beneficial effect of the gasfilling, which permits operation of the filament at a higher temperature. While nitrogen at a pressure of approximately 1 atm. was used in the first experiments, the lower thermal conductivity of argon made the use of this latter element even more desirable. The production of argon on a commercial scale was therefore undertaken and the argon-filled lamp was marketed in 1915.

The coiled-coil[1] lamp which made its advent during the last decade followed in logical sequence from Langmuir's original work. By the production of a stable filament, shorter in length than the single coil filament of equivalent output, convection losses were reduced to an extent which allowed of a material increase in efficiency for the same designed life. At a still later date krypton was produced in sufficient quantity to enable it to be used with advantage, from the point of view of efficiency, for gasfilling certain types of special small lamps. Improvements in vacuum technique and the manufacture of special glasses, together with parallel developments in associated fields, have rendered possible the production of tungsten filament lamps of a great variety of types, operating at efficiencies many times that of

[1]See Figure 6.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

the first carbon lamp. Typical examples of special projector lamps are shown in figure 7.

The earliest experiments on glow and arc discharges in gases and metallic vapours were stimulated by the fascination of the observed phenomena; the utilitarian aspect was hardly recognized. Indeed, it is only within the last two decades that results of outstanding commercial importance have been achieved. It was characteristic of early gas discharge tubes, which owed their luminosity to the positive column, that the brightness of the glow was extremely low and, in general, that a high voltage was necessary for their operation. The discharge tubes of Geissler, Crookes, Hittorf, and others, although little more than laboratory toys, were the forerunners of the Cooper Hewitt mercury vapour lamp (1900), the Moore carbon dioxide tube (1916), and the neon tube of Claude (1920). For a long time it appeared that the production of light by the electrical discharge was destined to be limited to tubular lamps of considerable size compared with tungsten filament lamps of equivalent light output. Development was given a new impetus, however, when it was found possible to apply the emissive alkaline earth cathode to gaseous discharge devices, a step which made possible the production of metallic vapour lamps of reasonable size and high light output, capable of striking directly on ordinary supply mains voltages. The first of such lamps to be made available for general illumination purposes employed a filling of sodium, and a necessary prerequisite of its successful development was the production of a special glass capable of withstanding the action of hot sodium vapour without darkening. The high efficiencies obtained with this lamp are due to the favourable position of the resonance radiation from sodium in relation to the peak of the visibility curve for the average eye. Commercial types of lamp of 85 watts and 140 watts rating have an initial efficiency of about 70 lumens per watt, practically the whole of the radiation being emitted at the wave-lengths 5,890–5,896 A.

The element which has proved most useful, however, for producing the vapour filling of modern discharge lamps is mercury, not only on account of its spectral characteristics, but also because of its comparatively low boiling-point. The last few years have witnessed a most varied series of developments in utilizing the properties of electrically excited mercury vapour under different conditions. A summary of the most important of these is given in the next column:

Mercury Vapour Pressures	*Lamp Type and Characteristics*	*Function*
C. 0·01 mm.	Mains voltage and high voltage tubing with inner surface coated with fluorescent powder. Low brightness and high efficiency	General and decorative lighting
C. 0·5 to 5·0 atm.	Mains voltage with hard glass or quartz discharge tube mounted in outer tubular envelope. High efficiency	General and street lighting
	Mains voltage discharge tube mounted in bulb coated with fluorescent powders. High efficiency and improved colour	General lighting where improved colour rendering is desirable
5·0 to 100 atm.	Mains voltage approximately spherical light source operating in quartz bulb. High efficiency and very high brightness	Projection work and to replace arc lamps
	High voltage linear source water-cooled. High efficiency and brightness	Projection work or where line source required

In the first group of lamps, in which the operating mercury vapour pressure reaches about 0·01 mm., the primary effect of the discharge is to produce mercury resonance radiation at the wave-lengths of 1,850 A and 2,537 A. This ultraviolet radiation is absorbed by, and thus renders luminous, a mixture of fluorescent powders coated on the inner surface of the tube within which the discharge takes place (*see* ENDEAVOUR, 1943, II, No. 5, 25).

The nature and composition of the fluorescent powder mixture can be controlled in such a way that the resultant light, produced at an efficiency of about 35 lumens per watt, has a quality very similar to that of the daylight sky. Alternatively, tubes exhibiting a wide range of colours can be produced, and these were made available in Great Britain some seven or eight years ago in the high-voltage pattern. It was not, however, until the advent of the mains voltage lamp, which was introduced in America in 1938 and in Britain in 1940, that the widespread adoption of fluorescent lighting was assured. For the present, manufacture in Britain is being confined to a fluorescent daylight lamp of 80 watts rating, but there can be no doubt that after return to normal conditions developments in both colour and lamp size may be anticipated. A characteristic and important feature of this type of light source is the low intrinsic brilliance, which in the case of the 80 watt lamp is of the order of 0·5 candle per square centimetre.

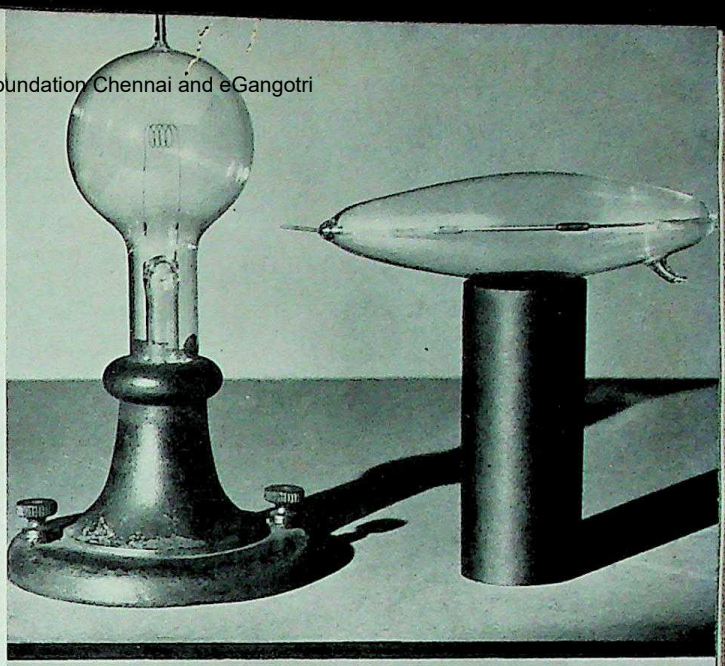
The light from lamps in the second and third groups is produced directly from the electrically excited mercury vapour. The correct working pressure is attained only after sufficient time has elapsed for the glass or quartz vessel in which the discharge takes place to reach a temperature

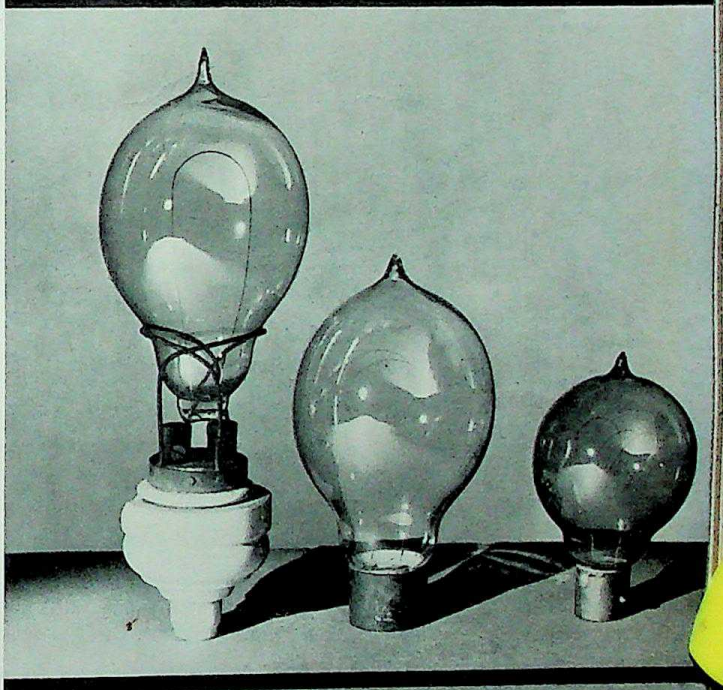
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

above the boiling-point of mercury. It is apparent, therefore, that the design of the lamp bulb must be such that its surface is substantially isothermal in order to avoid overheating of any section. Account must also be taken of the need for relating the allowable working temperature of the lamp bulb to the nature and properties of the material of which it is composed. Special borosilicate glasses have been developed for the 250 and 400 watt mercury lamps, and quartz is used for lamps of higher pressure where the temperature requirements are more stringent than even these glasses will tolerate. A typical lamp of the 400 watt type, developed primarily for street lighting, is shown in figure 8. The coefficient of expansion of the high silica-content glasses or of quartz itself is much lower than that of the special wires used for producing vacuum-tight seals used in incandescent lamp manufacture. It was found possible, however, so to relate the expansion-characteristics of the glass to those of tungsten or molybdenum that satisfactory direct seals could be made capable of operating at the high working temperatures (*c.* 500° C) which obtain in these lamps. The problem of producing direct hermetic seals through quartz was, however, much more complex, and has occupied several years. Its satisfactory solution has opened up new fields of development which have already yielded fruit in the form of extra high-pressure metal vapour lamps of extreme brightness.

It is significant that the spectrum of the mercury arc produced under the conditions of high vapour pressure and current density which obtain in certain modern lamps bears a strong resemblance to that of an incandescent body. This effect is shown in figure 9, where the spectra of mercury lamps belonging to the three main groups are compared. As the pressure is increased the position of maximum energy shifts from the resonance wave-length at 2,537 A towards the emission lines in the visible spectrum, resulting in an increase in the efficiency of light production. The possibilities of more effectively utilizing this phenomenon are by no means exhausted and work is proceeding.





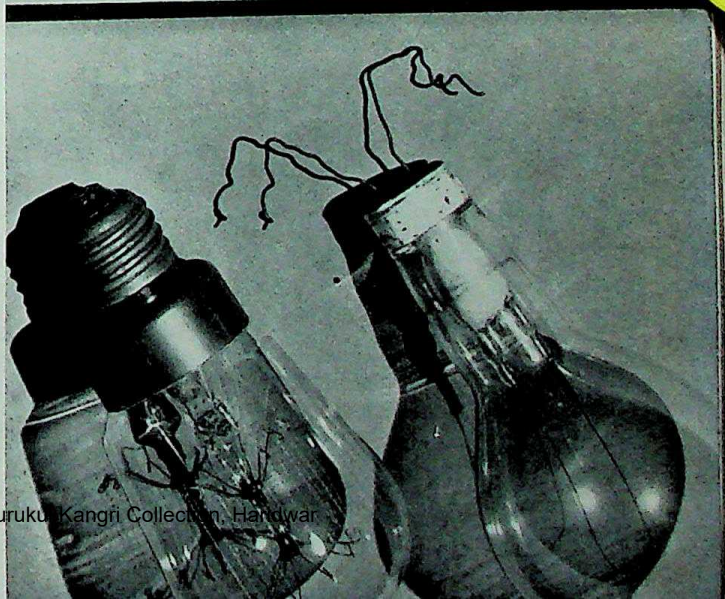


FIGURE 1 (*top*) – *Left, Edison lamp*, 1879; *right, Swan lamp*, 1878.

FIGURE 2 (*middle*) – *Various carbon lamps*, 1880–90.

FIGURE 3 (*bottom*) – *Left, tantalum*, 1905; *right, Lane Fox*, 1882.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

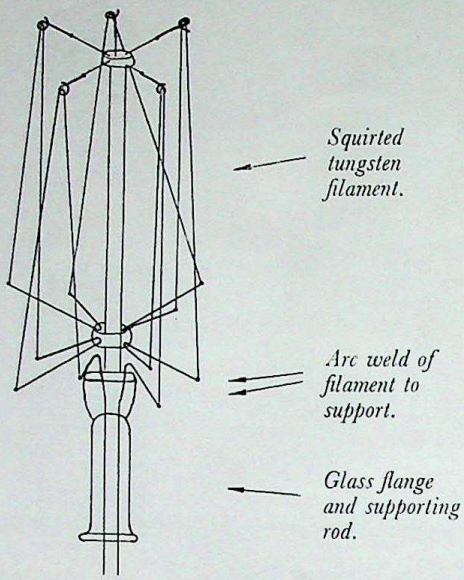
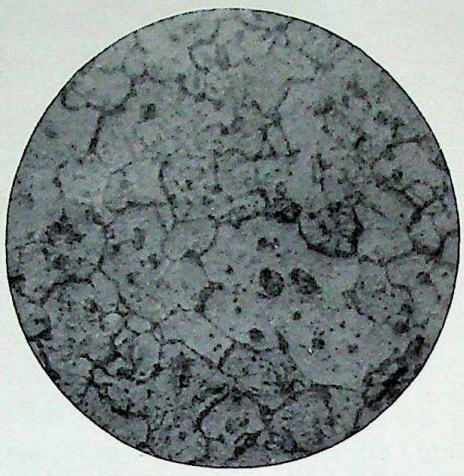
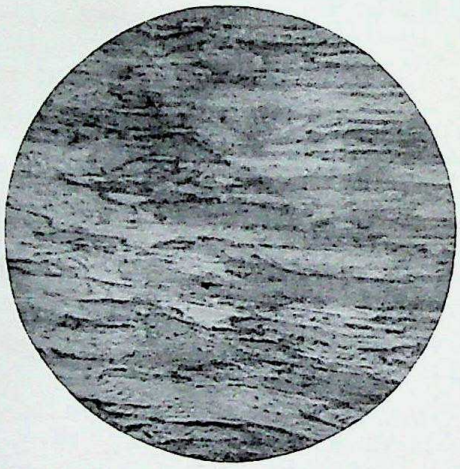


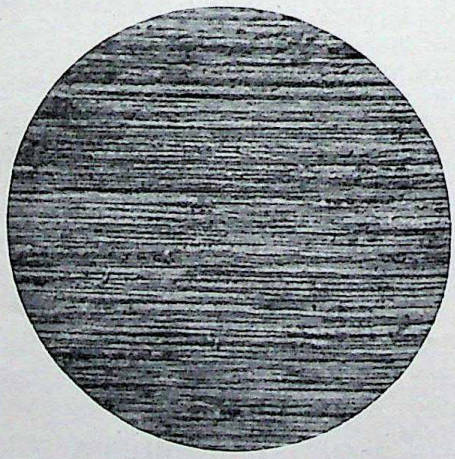
FIGURE 4



Sintered bar, 7 mm. square.



Swaged rod, 4 mm. diameter.



Drawn wire, 0·4 mm. diameter.

FIGURE 5

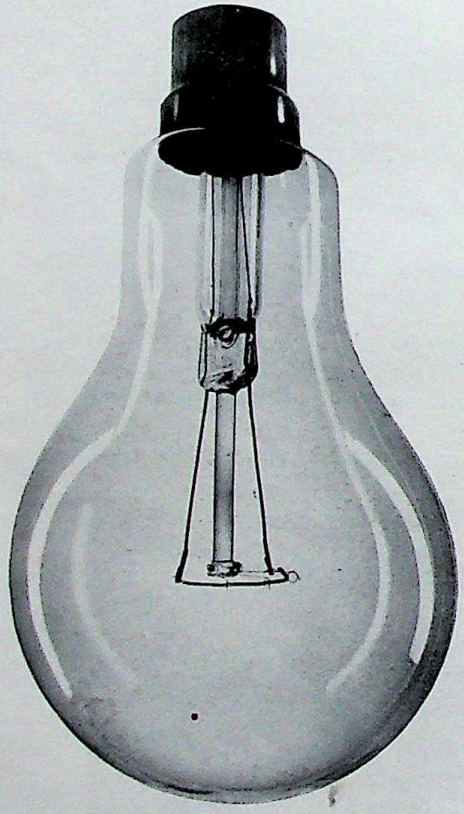
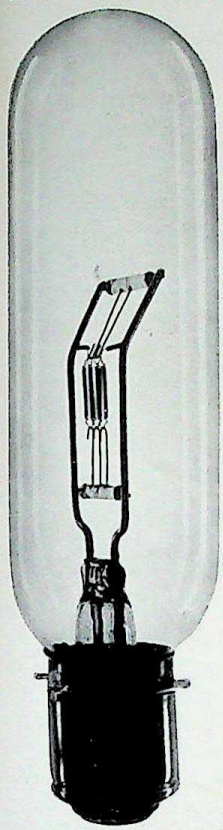


FIGURE 6 – *Coiled-coil lamp.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri



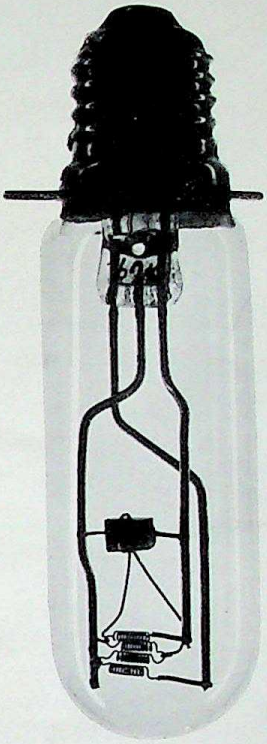


FIGURE 7 – *Projector lamps.*

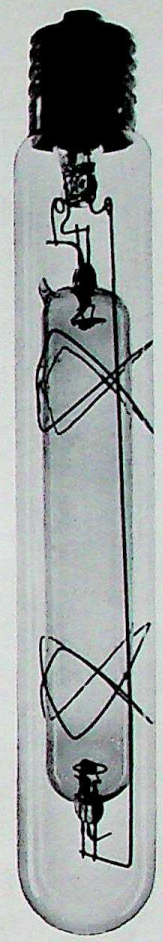


FIGURE 8 (*right*) – 400 *watt high-pressure mercury lamp.*

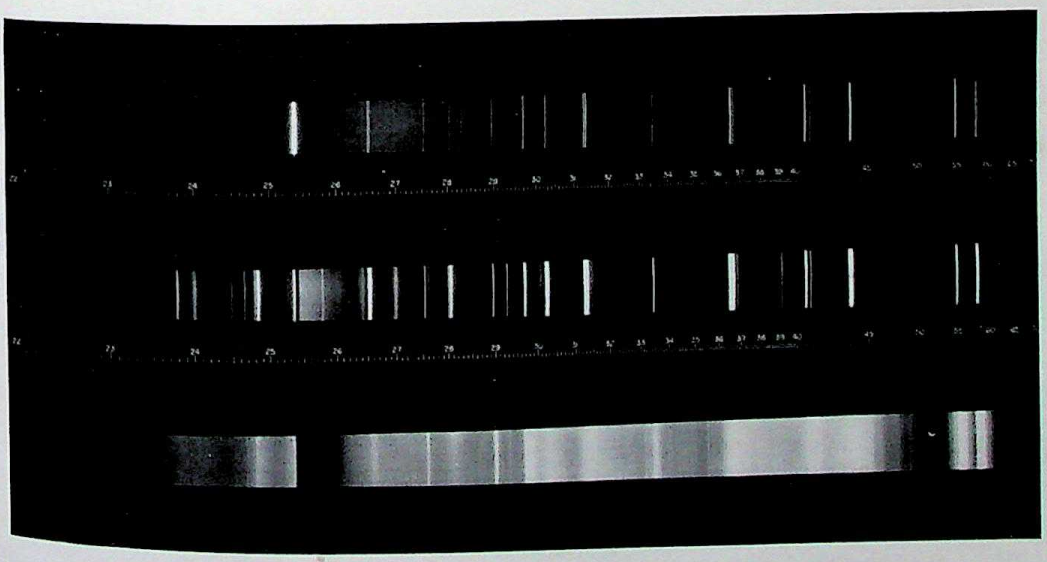


FIGURE 9 – *Spectra of mercury discharge at various pressures.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

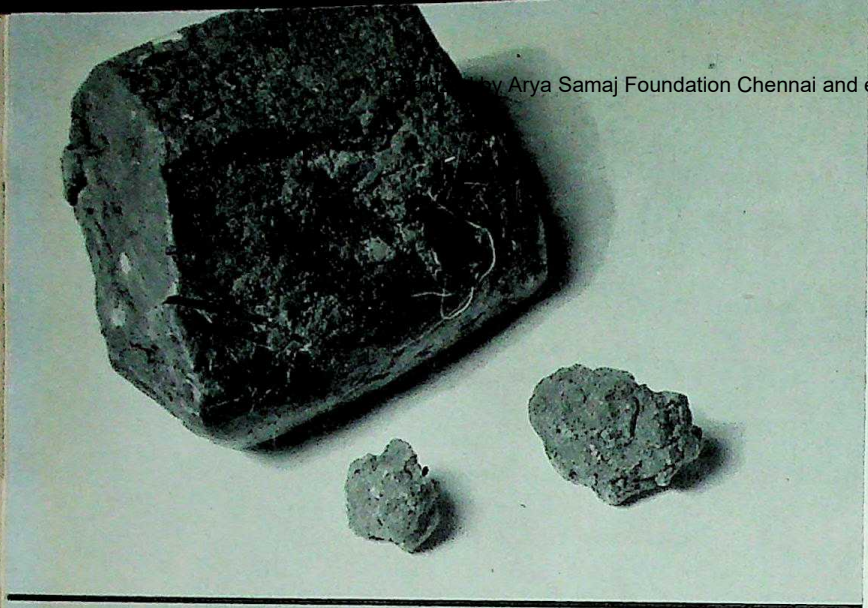


FIGURE 2 – *Crude hemp resin; samples of Indian charas.*

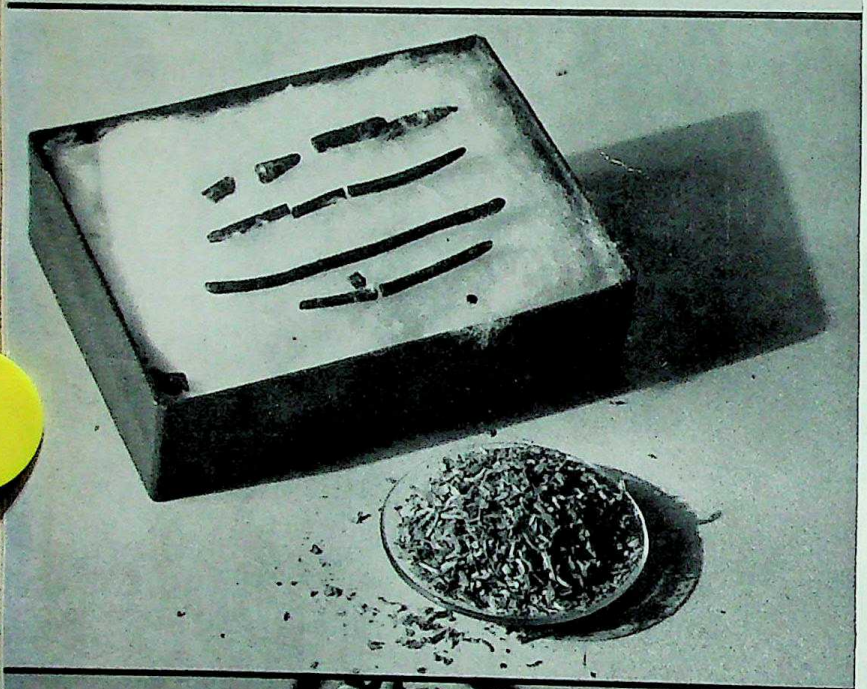


FIGURE 3 – (*Above*): *hashish moulded into thin rods for insertion into cigarettes;* (*below*): *kif, chopped flowering tops from North Africa, for use mixed with tobacco in cigarettes.*

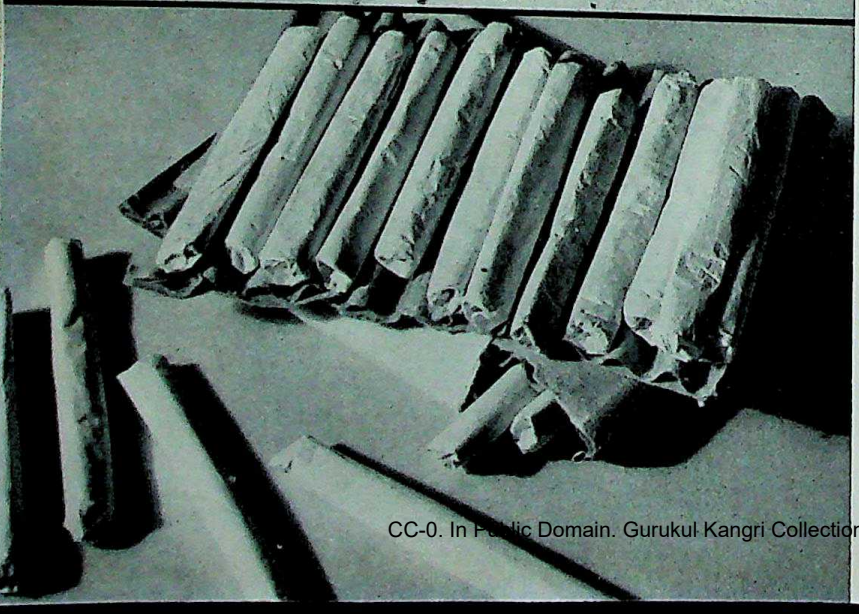


FIGURE 4 – *Marihuana cigarettes, indicating one method of smuggling. The cigarettes are inserted into the folds of corrugated wrapping paper.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The hemp drugs

A. R. TODD

The Assassins, Saracen sectarians notorious for their secret murder of Crusaders, owed their name to their practice of eating hashish as an intoxicant: an assassin is etymologically a hashish-eater. The chemical nature of the intoxicating principle in hashish has proved a difficult problem to solve. Professor Todd describes recent progress towards its solution.

Hemp (*Cannabis sativa*, L.) has been commercially important for thousands of years both for the fibre which it yields and for the oil obtained from its seeds. Knowledge that it produces an intoxicating principle is of almost equal antiquity, and the use of hemp preparations as medicaments, and more particularly as drugs of addiction, has long been prevalent in many parts of the world. The plant is an annual which can be grown almost anywhere from the temperate zone to tropical regions. It is dicœcious, the male and female flowers occurring on separate plants, and the female flowering tops are covered with tiny glandular hairs which secrete a greenish resin believed by some to protect the ripening seeds. This resin, the active component of which also occurs in smaller amount in other parts of the plant, has a powerful physiological action and forms the basis of the various hemp drugs. The amount of resin produced and its activity vary considerably according to variety and the locality in which the plant is grown. Precise figures are difficult to obtain, but it is generally agreed that varieties grown in Asia (probably the original habitat of the plant) are the best producers of active resin. The varieties cultivated for drug production are generally smaller in size than those grown for fibre. The hemp drugs are known by a host of names according to locality and mode of preparation, i.e. whether prepared from the resin itself or leaves and tops, or from decoctions of the plant. Among the more common are *charas*, *ganja*, *bhang* (India); *hashish* (Egypt, Asia Minor); *kif* (North Africa); and *marihuana* (North, Central, and South America). Of these, hashish is perhaps the most familiar to European ears; it is indeed frequently applied as a kind of generic term for the hemp drugs. As most preparations of the type mentioned appear only on the illicit market, their precise mode of preparation is frequently rather obscure and their quality often uncertain.

FIGURE 1 – *Hemp* (Cannabis sativa). *Female flowering top.*

Historically, the use of hemp drugs was known in India two thousand years ago, and is so well established that the plant has assumed a divine status in some parts of that country. Curiously enough, although hemp has been applied medically in China since remote times, there is little evidence of its abuse in early records. The hemp drugs have long been used in the Near East, and have been a very serious problem in Egypt. They have never been much in evidence in Western Europe, and the use of hashish there is not recorded before the middle of the eighteenth century, when efforts were made to introduce it into medicine. The idea that the comparative absence of the vice from Europe was due to temperamental incompatibility is exploded by its spread in the United States, where, following the introduction of marihuana from Mexico, its abuse has advanced so rapidly that it is now a major drug problem in that country, and strict measures have been adopted to counter it.

Hemp preparations are usually eaten or smoked, the effects being, as might be expected, slower in developing when the preparations are eaten. To give an accurate picture of the effects of hashish is extremely difficult, partly because they are more subjective than objective,

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

and because individual variation in response is probably greater with this than with any other drug. Many subjective descriptions of hashish intoxication are extant, but a number of the more widely known are based upon highly coloured accounts written by literary dabblers in the vice (e.g. the description given by Alexandre Dumas in *The Count of Monte Cristo*). It is for this reason that popular ideas of hashish effects are frequently erroneous. It seems clear that the primary effect of the drug is on the central nervous system and that peripheral effects are few. Among the commonest recorded effects are a feeling of well-being alternating with depression, distortion of time and space, and double-consciousness. Objectively there is a period of excitation and exaltation, followed often by sleep or coma. It is said that the taker of hashish suffers from no 'hangover' and that the drug, although it leads to moral deterioration, is not physically habit-forming, in the sense that there are no physical withdrawal symptoms such as are found in morphine addiction. Hemp preparations have been applied medically without a great deal of discrimination for a host of complaints with varying success, but they have fallen into disrepute mainly through the extreme variation in potency of the material employed, coupled with a lack of any reliable assay procedure and a general fear of addiction.

Until recently, exact scientific knowledge—both chemical and pharmacological—of the hemp drugs was very scanty. This is to be attributed to the rather intractable nature of the active resin, which long defied attempts by chemists to isolate pure substances from it, and to the lack of any animal test which was reliable and which gave results at all comparable with the effects observed in human beings. Since progress in chemical investigation of a drug is dependent on satisfactory biological testing, it is perhaps well to mention at the outset that two methods are used to assay hashish activity, one depending on the ataxia produced in dogs and the second on production of corneal anaesthesia in rabbits by intravenous injection (Gayer test). The relative potencies of various preparations are not always strictly parallel when measured by these tests, and the relationship between them requires further study. Recent work indicates that potency in dogs as measured by the ataxia method closely parallels that observed in human beings.

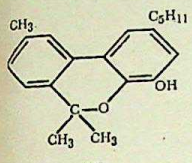
Chemical investigation of the hemp drugs has been carried on sporadically for nearly a century, the starting material being in all cases the resinous active material extracted from prepared drugs or from the plant source. It was found as early as 1857, by the brothers T. and H. Smith, that the hashish activity resided in the alkali-insoluble high-boiling portion of the resin, and that it was nitrogen-free—a surprising discovery since most people at the time expected the active principle to be, like those of opium and tobacco, an alkaloid. Later on, between 1895 and 1900, Wood, Spivey and Easterfield, and Dunstan and Henry, isolated from the active portion of the resin prepared by vacuum distillation a homogeneous viscous oil yielding a crystalline acetate. To it the name cannabinol was applied and some preliminary examination of it was carried out; but little real progress was made for another thirty years, when Cahn, in a series of elegant researches, went far to clarify its structure, and incidentally indicated that it was probably not, as had hitherto been assumed, the active principle of hashish. The absence of progress in the intervening period seems to have been due in the main to the fact that the various investigators who endeavoured to follow up the earlier work either failed to repeat the isolation of cannabinol or were deceived by the relatively narrow boiling range of the crude active resin into assuming it to be homogeneous. Between 1932 and 1934 Cahn established the carbon skeleton and the nature of the substituent groups in the molecule of cannabinol, and proposed for it structure (I) in which only the positions of the hydroxyl and *n*-amyl groupings remained uncertain. Unfortunately Cahn's researches were broken off at this stage and several years passed before the active resin was again studied. Since 1938 extended investigations by Todd in Great Britain and Adams in America, with their collaborators and associated pharmacologists, Macdonald and Loewe, have thrown a good deal of light on the subject. The British workers have used as sources of material mainly Indian hemp resin in the form of ganja and Egyptian hashish, while the Americans have used marihuana.

It was quickly found that cannabinol could be readily isolated from the distilled active resin from Indian ganja as its crystalline ester with *p*-nitrobenzoic acid, and that it was devoid of hashish activity, the active principle remaining in the non-crystalline portion of the esterified resin. From the fact that cannabinol gave a positive indophenol reaction showing that the *para*-position to the phenolic hydroxyl group was unsubstituted,

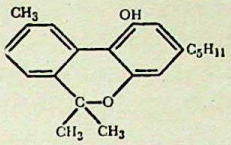
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

and from the results of nitration, it was deduced that of the twelve structures for cannabinol which were possible from Cahn's results only (I) or (II) could represent that substance.

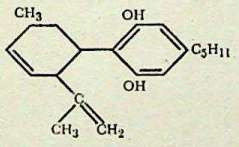


(I)



(II)

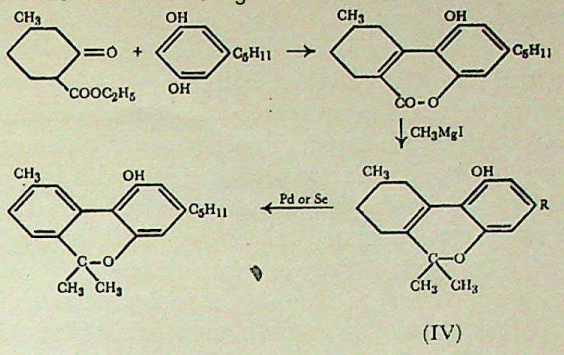
A decision between these two formulae became possible through the isolation and study of another constituent of hemp resin. In working up resin from marihuana, Adams isolated a dihydric phenol to which he gave the name cannabidiol. Simultaneously, Jacob and Todd, in the course of work on Egyptian hashish, observed that crude cannabinol from this source was contaminated with a second phenol which proved to be identical with cannabidiol from marihuana. It is of some interest to note the variation in the content of cannabinol and cannabidiol in drugs of different origin. The Indian drug seems to contain very little cannabidiol and the American little cannabinol; Egyptian hashish occupies a midway position in this respect. Cannabidiol, like cannabinol, is devoid of hashish activity, and is the substance mainly responsible for the *Cannabis* reaction known as the Beam test (purple coloration with alkali); available degradative evidence suggests for it the structure (III) although it has not yet



(III)

been synthesized in the laboratory. The orientation of the hydroxyl groups in cannabidiol, proved by the production of olivetol (5-*n*-amylresorcinol) from it by pyrolysis with pyridine hydrochloride, together with the simultaneous occurrence in hemp of cannabidiol and cannabinol, led to the conclusion that the molecular structure of the latter must be represented by (II). This conclusion was verified by two independent and well-nigh simultaneous syntheses of cannabinol by Adams, Baker, and Wearn, and by Ghosh, Todd, and Wilkinson.

The synthetic method of the latter workers, indicated schematically above, is of particular



(IV)

interest because the intermediate tetrahydrocannabinol (IV; R = n-C_5H_{11}) has been found to show the typical physiological effects of hashish in rabbits, in dogs, and in man. With a view to establishing the structural features necessary for exhibition of this activity, a large number of analogues of synthetic tetrahydrocannabinol in which the molecule was modified in various ways has been synthesized by this method both in Great Britain and in America. While the results of these studies cannot be discussed in detail here, it is interesting to note that in homologues of (IV), where only the group R varies in size, activity in the n-alkyl series rises from methyl to a maximum at n-hexyl, and then decreases again. The synthetic tetrahydrocannabinol (IV; R = n-C_5H_{11}) as ordinarily obtained is, of course, optically inactive, whereas it is known that the natural physiologically active resins are strongly laevorotatory. By using suitable starting materials, however, the pure dextro- and laevorotatory forms have been synthesized and the latter shown to be several times more active than the former, although still considerably less so than highly purified natural resin. The synthetic substance we have been discussing is not the only tetrahydrocannabinol to show hashish activity. Adams has shown that by heating with acid catalysts cannabidiol (III) is converted to a mixture of highly active tetrahydrocannabinols differing from each other and from synthetic tetrahydrocannabinol in the location of the ethylenic linkage in the left-hand ring, or stereochemically, or both.

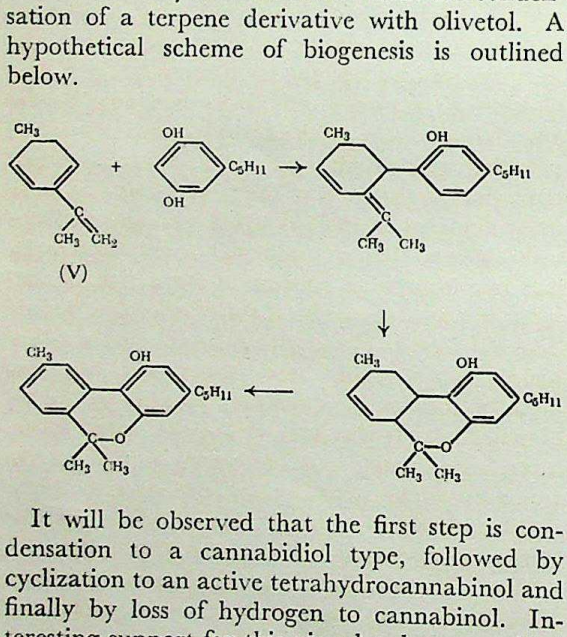
The isolation of the homogeneous active principle from hemp resins freed of terpenes, hydrocarbons, cannabinol, and cannabidiol has proved a very difficult matter. From Indian and Egyptian material products have been obtained with physiological potency greater than that of any of the synthetic substances mentioned above. Analysis of these various products suggests that they are isomers of synthetic tetrahydrocannabinol, and,

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

in conformity with such a view of their structure, they contain one ethylenic linkage and yield cannabinol on dehydrogenation. As they are resins from which no crystalline derivatives have as yet been prepared, absolute proof of homogeneity is difficult to obtain. All evidence at present available, however, justifies the view that hemp resins contain a mixture of physiologically active isomeric tetrahydrocannabinols.

Speculation as to the way in which physiologically active substances are elaborated in plants is always attractive, and some attention has been given to this in the case of the typical hashish constituents. Examination of the formula of cannabidiol (III) shows that scission of the bond linking the two rings would leave on the left a substance belonging to the terpene group of natural products which form the major constituents of essential oils, and on the right olivetol, a common constituent of the class of plant products known as depsides. This leads to the suggestion that cannabidiol, tetrahydrocannabinols, and cannabinol may arise in nature from the condensation of a terpene derivative with olivetol. A hypothetical scheme of biogenesis is outlined below.



(V)

It will be observed that the first step is condensation to a cannabidiol type, followed by cyclization to an active tetrahydrocannabinol and finally by loss of hydrogen to cannabinol. Interesting support for this view has been provided by Simonsen and Todd through examination of the 'terpene fraction' obtained in the distillation of Egyptian hashish. The lower-boiling portion consisted mainly of *p*-cymene and methyl-4-isopropenylbenzene. Now a menthatriene (V), if it existed as a synthetic intermediate in the plant, would be unstable and would probably be converted by isomerization or dehydrogenation into these two compounds which are actually found in bulk in the resin. It is worth noting, too, that the hypothetical scheme outlined gives a rational explanation of the variation in composition and potency of hemp resin obtained from different localities.

Efforts have, of course, been made to realize at any rate parts of the above scheme of biogenesis in the laboratory. The conversion of cannabidiol to active tetrahydrocannabinols and of tetrahydrocannabinol to cannabinol has already been mentioned. As regards the initial stage, the menthatriene (V) is rather inaccessible, but by condensing the readily available terpene derivative *d*-pulegone with olivetol, a physiologically active product has been obtained from which the dextrorotatory form of the tetrahydrocannabinol (IV; R = n-C_5H_{11}) has been isolated. This compound is accompanied in the product by at least one other inert substance which is probably a xanthene derivative; whether substances like the latter are also present in hemp resin is as yet unknown.

Such, then, is a general outline of the present position regarding scientific investigation of hashish. It is clear that much further chemical and pharmacological work remains to be done before complete understanding is attained, but the foundation for such an understanding would appear to have been laid. On the practical side, too, the fact that pure synthetic substances showing the typical activity of *Cannabis* are now available will, it is hoped, lead to their clinical examination and possibly to the discovery of medical applications for this interesting group of compounds.

In conclusion, the author would like to acknowledge here his indebtedness to Mr F. Thornton of the Home Office (Drugs Branch) for facilities to obtain the illustrations reproduced in this article and for his co-operation in the course of many of the researches discussed.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Vitamin D

LADY MELLANBY

Lady Mellanby was present at the birth of vitamin D in 1918, and might indeed be regarded as midwife and nurse to a baby born after a difficult labour and scornfully received. Here she describes its development into a lusty adult of enormous importance to human welfare, but adds that vitamin D is still the greatest single deficiency in the diet of Britain.

When it was discovered by experiments on puppies, made in England during the first world war, that rickets was a disease due to insufficiency in the diet of an antirachitic or calcifying vitamin which was 'either identical with fat-soluble A or has a natural distribution somewhat similar to vitamin A,' a remarkable chapter of scientific investigation was begun, which continues to this day. The discovery had widespread influence, partly because of its great practical implications. In the first place, it provided the immediate means of preventing and curing rickets (see figure 1), one of the commonest and most deforming diseases of Western civilization. Secondly, it opened up a new chapter of dental science by showing that the structure of the teeth depended on specific substances in the food eaten during the time of their development, and especially upon the intake of a calcifying vitamin. This is illustrated in figure 2.

The practical significance of the discovery was not, however, sufficient in itself to explain the great interest of scientific workers. To account for this, further explanation is necessary. Announcement of the presence of a calcifying vitamin in certain foods such as cod-liver oil, egg-yolk, milk, and some animal fats was at first met with much incredulity. Medical men did not believe that there was such a vitamin, but thought that rickets was mainly due to lack of hygiene, emphasis being put on confinement and insufficient exercise; massage and electrical treatment were often recommended to overcome the disease. Although none of these factors *per se* proved to be of major importance in rickets, hygiene did indeed play a part, as was shown when Huldschinsky discovered that rickets was cured by the exposure of the skin of babies to the ultra-violet radiations of a mercury-vapour lamp. The next few years were occupied in bringing together these two apparently remote factors controlling bone and tooth calcification—a fat-soluble vitamin (the dietetic factor) and something produced by ultra-violet radiations acting on the skin (the hygienic factor).

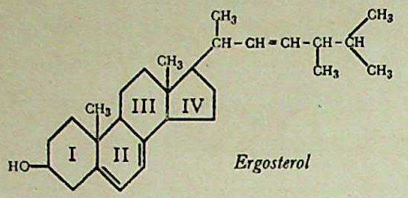
It is not necessary to repeat the well-known story leading up to the discovery that the beneficial effects of ultra-violet radiations from the mercury-vapour lamp and from the sun were also due to a calcifying vitamin and that, in fact, these radiations were of value simply because they transformed an inactive sterol—the provitamin of the skin—into an active vitamin. This phenomenon was at the time something quite new in physical and biological science, and it elucidated the hitherto unsolved problem as to why the native children in tropical zones rarely developed rickets and dental caries, whereas both diseases were so prevalent in temperate zones. It became evident that, though the diets of the tropical natives were often deficient in the calcifying vitamin, perhaps even more so than in temperate zones, they really had ample supplies because of the action of sunlight on the provitamin of their little-clad bodies. The Eskimos in the arctic regions, on the other hand, had straight, hard bones and beautiful teeth because of the calcifying vitamin in the fat of their food. It was later shown that many foods, including cereals, also contained a provitamin which could be activated by exposure to ultra-violet radiations. The beneficial effect on the teeth of food treated in this way is seen in figure 3.

Much information was gradually obtained about the actual transformation of ergosterol, by ultra-violet radiations, into the calcifying vitamin, now called vitamin D. The change was shown to involve the formation of a series of chemical substances: ergosterol → lumisterol → protachysterol → tachysterol → vitamin D (in Britain often referred to as calciferol). Calciferol itself was also liable to be broken down further to inactive substances—toxisterol and suprasterols I and II. It was found to be an isomer of ergosterol, and the effect of the ultra-violet radiations was to open

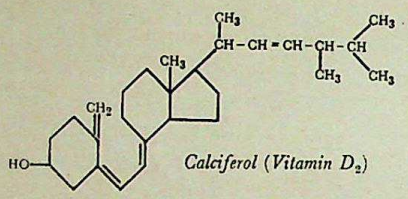
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

up the phenanthrene nucleus between carbon atoms C_9 and C_{10} in ring II, the formulae of the two substances being:



Ergosterol



Calciferol (Vitamin D_2)

Chemists next proceeded to show that the activation of ergosterol into a calcifying vitamin was only one of a number of similar reactions. At least nine other sterols were found to act as provitamins D and to be transformed into substances with powerful calcifying actions by exposure to the same part of the ultra-violet spectrum as that which converted ergosterol into calciferol, namely wave-length 260–300 mμ, and in each case the active substance was isomeric with the parent substance.

Fortunately the physiological problem was simplified to some extent by the acceptance of the fact that, although this was a vastly interesting study to the chemist, only two of the provitamins were of important biological interest, viz. ergosterol and 7-dehydrocholesterol. It is now usual to call the vitamin produced from ergosterol (calciferol) vitamin D_2, and that from 7-dehydrocholesterol vitamin D_3. (Vitamin D_1 is the molecular addition product of D_2 and lumisterol.) Vitamin D_3 bears the same chemical relationship to 7-dehydrocholesterol as vitamin D_2 does to ergosterol. The ring structure of vitamin D_2 (given above) and D_3 is identical, but the side-chain of the former is that of ergosterol and of the latter that of cholesterol.

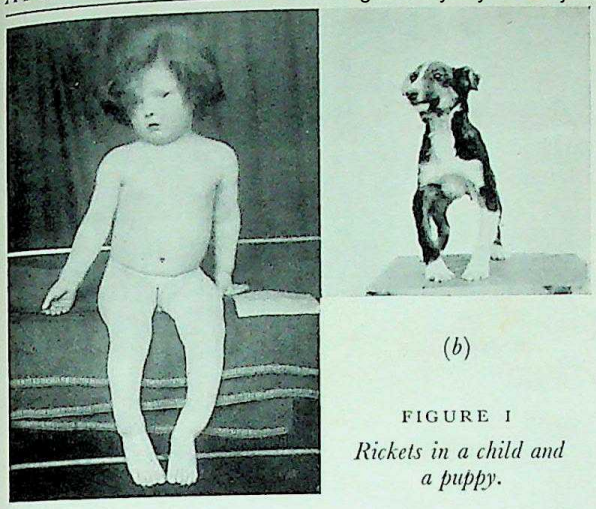
So long as ergosterol was the only known provitamin D, it was assumed that the vitamin D of vegetable and animal life was activated ergosterol. There is no evidence that the vitamin can be formed in higher animals in any other way than by ultra-violet radiations acting on a provitamin in their skin. All present experience indicates that, if animals get no vitamin D in their food and are not exposed to ultra-violet radiations, they will suffer from the specific ills due to vitamin D deficiency. Fish, which are naturally beyond the influence of ultra-violet radiations, were therefore supposed to get their vitamin D from plankton and algae which, floating on the surface of the sea, had been exposed to sunlight; cows got their vitamin D either from grass exposed to sunshine or from the effects of sunshine on the provitamin in the skin. These hypotheses were shaken by the discovery that the main vitamin D of vertebrate animal life was not activated ergosterol (vitamin D_2) but activated 7-dehydrocholesterol (vitamin D_3). There remains indeed a gap in our knowledge concerning the relation of the vegetable provitamin, ergosterol, to the chief animal provitamin, 7-dehydrocholesterol.

So far as is known at present, vitamins D_2 and D_3 have similar modes of action in the human body; vitamin D_2, however, has little effect on bone formation in birds, and for this reason the poultry farmer gives a fish-liver oil to his chickens rather than irradiated ergosterol. Incidentally it may be remarked that the dog breeder and poultry farmer were comparatively quick off the mark in using the new therapy.

Vitamin D seems to have two general effects in the body, although both may be due to one type of action. In the first place it facilitates the absorption of calcium and phosphorus from the alimentary canal, so that a more plentiful supply of these elements is available to the tissues. Thus, if a diet free from vitamin D is taken, as the body stores of the vitamin are gradually reduced progressively smaller quantities of calcium and phosphorus are absorbed and greater quantities are excreted in the faeces. At first this lack of vitamin D in the food can be overcome by increasing the calcium and phosphorus intake; but when all the body stores of the vitamin are lost, this compensation tends to break down and the additional elements are rejected. The vitamin also appears to control the incorporation of the calcium and phosphorus carried by the blood into the tissues of the developing bones and teeth. Present evidence suggests that, in the absence of vitamin D from the body, even if the necessary calcium and phosphorus were injected directly into the bloodstream, little or none would be incorporated in the tissues needing them. In other words, vitamin D appears to be the key to the availability of calcium and phosphorus in the tissues; when there is abundance of this vitamin in the body, good

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri



(a) (b)

FIGURE 1
Rickets in a child and a puppy.

(a) *A child with rickets, as evidenced by some bowing of the legs and swelling and deformity of the wrists and ankles. Very much worse cases of the disease were seen in industrial areas before and during the first world war.*

(b) *A puppy with experimentally produced rickets roughly corresponding in degree to that of the child in (a). The diet of the puppy was deficient in the calcifying vitamin D. A similar diet with the addition of the vitamin results in a normal, straight-legged animal.*

The addition to the diet of either the child or the dog of $\frac{1}{20}$ *mg. of vitamin D daily (i.e. double the preventative dose* [*see p.* 78]) *would result in time in the straightening of the legs.*

bones and good teeth can be procured even with remarkably small supplies of these elements in the food and water.

The compounds of calcium and phosphorus in the food are not all equally available to the body. Indeed there is one important dietary constituent, phytic acid (inositol hexaphosphoric acid), which actually interferes with calcification by precipitating calcium in the gut and making it unavailable. The photographs of three puppies in figure 4 show this clearly. Under some conditions, and especially when vitamin D is deficient, phytic acid in the food can even deprive adult bones of their calcium and produce osteomalacia, a disease—characterized by a gradual softening of the bones—not often seen in England but common in the East. However, vitamin D can effectively clip the claws of phytic acid and even cause much of its phosphorus to be absorbed and to be beneficial rather than harmful. This fact is illustrated in figure 5. Phytic acid is abundant in cereals, especially in oatmeal and maize. The fact that cereals form such a large part of the British diet, which is often deficient in vitamin D and calcium, is one of the main reasons why our bones and teeth are so badly formed and why it is necessary to

Molar teeth of four children. *Molar teeth of four dogs.*

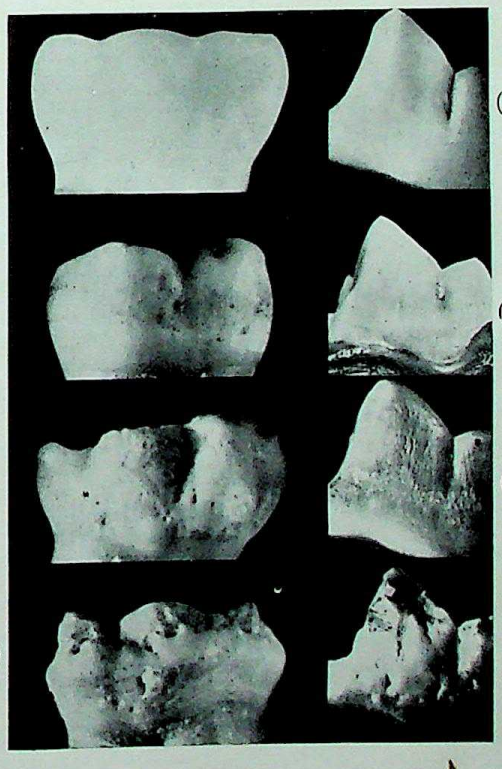


FIGURE 2 (*right*) – *Enlarged photographs of the surface enamel of human and dogs' molar teeth.*

(*a*) *and* (*e*) *Good structure; smooth and shiny.*

(*b*) *and* (*f*) *Slightly defective structure; some roughness.*

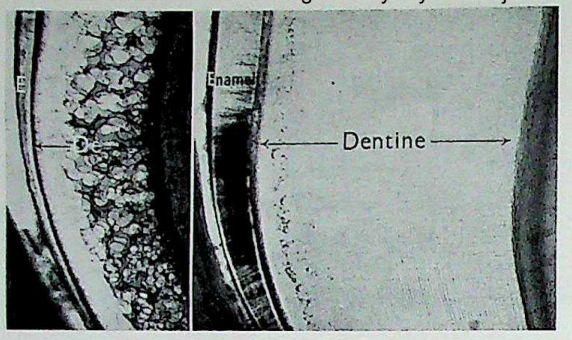
(*c*) *and* (*g*) *Very defective structure; rough.*

(*d*) *and* (*h*) *Grossly defective structure; comparatively large areas of deficient enamel.*

The dogs from which the teeth (*e*) *to* (*h*) *were taken had different amounts of fat-soluble vitamins, especially vitamin D, the dosage being progressively reduced, so that* (*e*) *had an abundant supply and* (*h*) *very little. By analogy, and on the basis of a few investigations on children whose diets were controlled, it seems reasonable to assume that the different types of enamel in these human teeth* [(*a*) *to* (*d*)] *are also due in the main to variations in the fat-soluble vitamins, and especially vitamin D, available at the time of their development.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

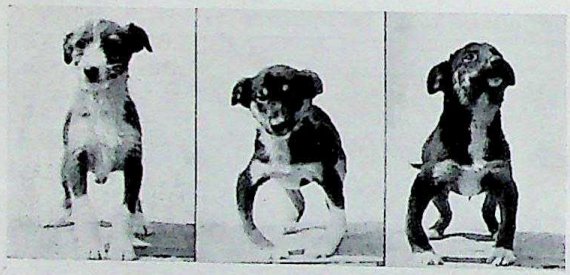


(*a*) (*b*)

FIGURE 3 – *The effect of ultra-violet light on the provitamin in cereals.*

Photomicrographs of sections from comparable parts of the molar teeth of two litter-mate dogs. Both had the same vitamin D-deficient diet, but the cereal of (a) was untreated, while that of (b) was exposed to ultra-violet radiations.

Note *in (a) the thin and poorly calcified enamel and dentine compared with the tissues in (b). The dark, irregular areas in the dentine represent poorly calcified tissue.*



(*a*) (*b*) (*c*)

FIGURE 4 – *The effect of phytic acid of oatmeal in the absence of vitamin D.*

Photographs of three puppies of one litter living under the same conditions. Their diets were similar, except as mentioned below, and all contained vitamin A, but were deficient in vitamin D.

(*a*) *had white flour which contained very little phytic acid.*

(*b*) *had oatmeal which contained much phytic acid.*

(*c*) *had white flour to which was added phytic acid extracted from oatmeal, in amount equivalent to the phytic acid in the oatmeal fed to (b).*

Note: *(a) has very little rickets, while (b) and (c) are very rachitic to about the same extent. The addition of vitamin D to any of these diets would have resulted in a normal, straight-legged dog.*

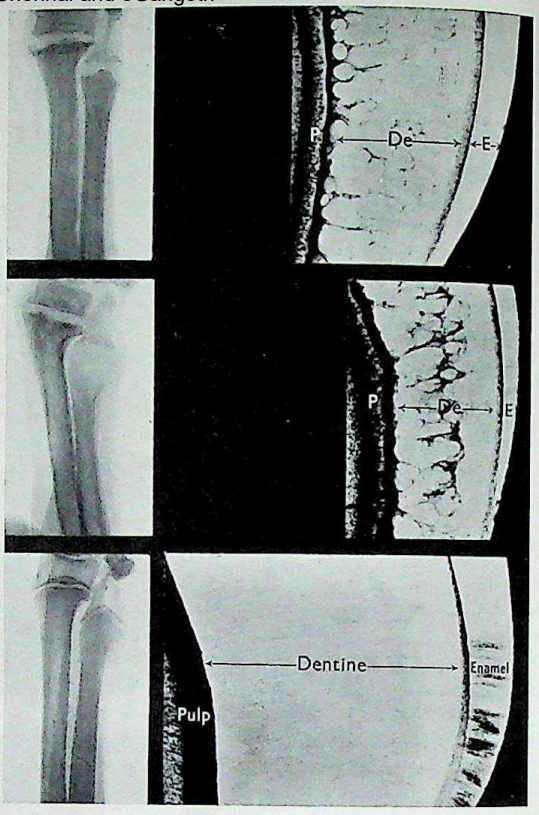


FIGURE 5 – *Phytic acid antagonized by vitamin D.*

X-ray photographs of the wrist-joints and photomicrographs showing sections from comparable parts of the teeth of three litter-mate dogs kept under identical conditions. All had a diet deficient in vitamin D but containing vitamin A.

(*a*) *had no additions.*

(*b*) *had 200 mg. of phytic acid added daily.*

(*c*) *had 200 mg. of phytic acid together with 2,000 international units of vitamin D added daily.*

The X-ray photographs show a medium amount of rickets in (a), much in (b), and none in (c).

The photomicrographs of the teeth show that in dog (b) the addition to the diet of phytic acid has resulted in thinner enamel (E) and thinner and less well-calcified dentine (De) than are found in (a). (This is indicated by an increase in the dark, poorly calcified areas.) The addition of vitamin D to the diet of (c) has more than counterbalanced the harmful effect of the phytic acid. The dentine of the tooth is thick and the structure is good, with none of the dark, poorly calcified areas so evident in (b), and appearing to some extent in (a).

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

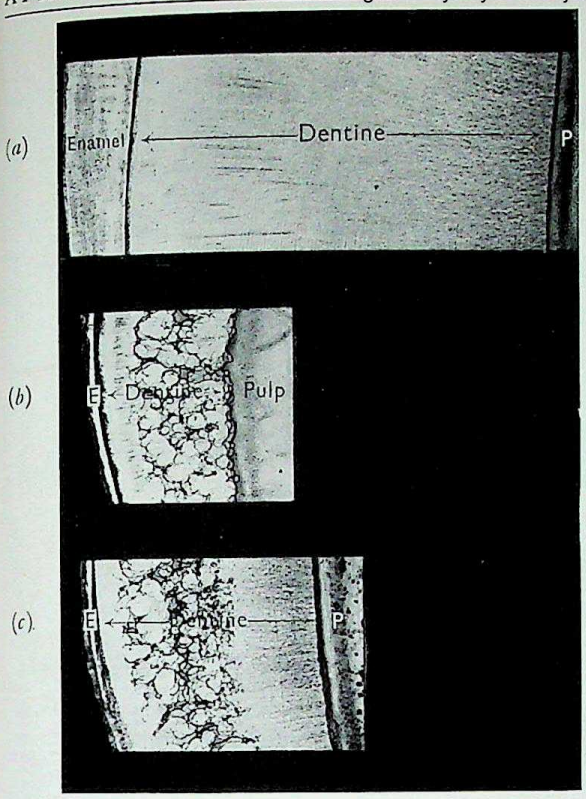
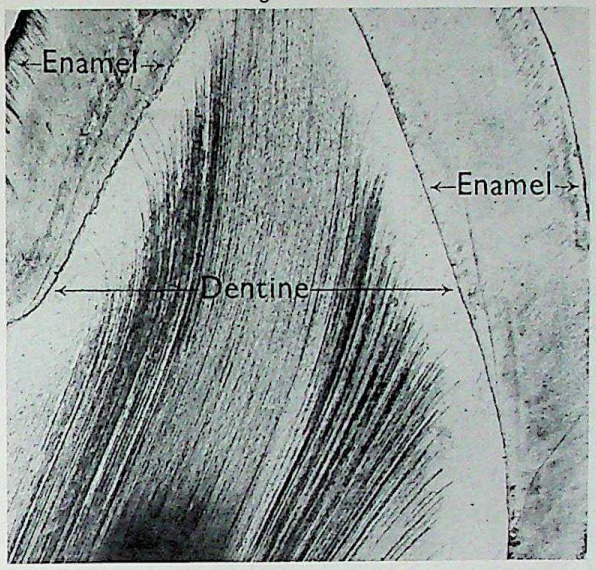


FIGURE 6 – *The effect of fat-soluble vitamins A and D on the teeth. Photomicrographs showing sections from comparable parts of teeth of three litter-mate dogs kept under identical conditions. All had oatmeal, separated milk powder, lean meat, orange-juice, yeast, and salt in their diet.*

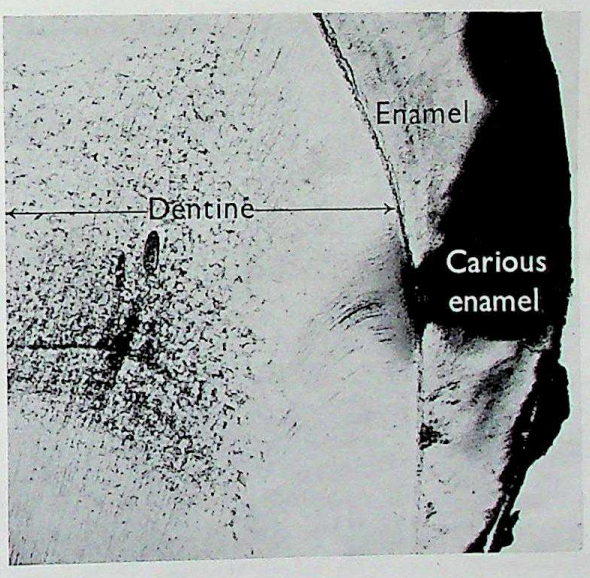
(a) *had an addition of fat-soluble vitamins in the form of cod-liver oil for the experimental period of five months. Both enamel and dentine are thick and well formed.*

(b) *had olive oil instead of cod-liver oil throughout the same experimental period. Both enamel and dentine are thin and the dentine is ill formed, with many poorly calcified areas (shown in black in the illustration).*

The diet of (c) *was devoid of fat-soluble vitamins for five months and then cod-liver oil was given for one month. The dentine laid down in the first period is very similar in amount and structure to that of* (b), *whereas that deposited in the last month is almost as thick as that laid down in the first five months and is as well formed as that of* (a).



(a)



(b)

FIGURE 7 – *Photomicrographs of sections from comparable parts of molar teeth of two children, showing different types of histological structure.*

(a) *Good structure; no poorly calcified areas in the dentine.*
(b) *Defective structure; many poorly calcified areas in the dentine (dark patches in the illustration).*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

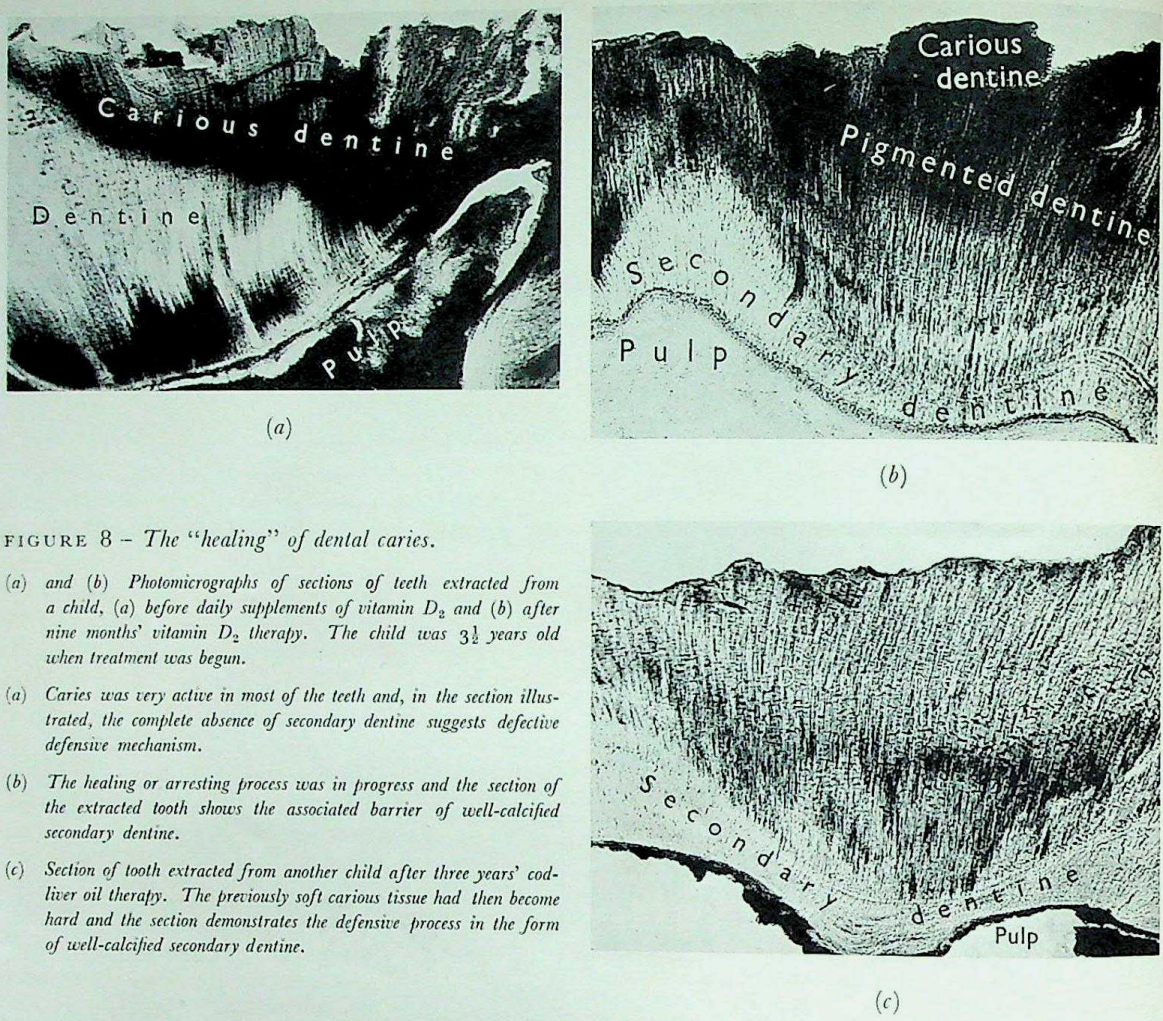


FIGURE 8 – *The "healing" of dental caries.*

(a) and (b) Photomicrographs of sections of teeth extracted from a child, (a) before daily supplements of vitamin D_2 and (b) after nine months' vitamin D_2 therapy. The child was $3\frac{1}{2}$ years old when treatment was begun.

(a) Caries was very active in most of the teeth and, in the section illustrated, the complete absence of secondary dentine suggests defective defensive mechanism.

(b) The healing or arresting process was in progress and the section of the extracted tooth shows the associated barrier of well-calcified secondary dentine.

(c) Section of tooth extracted from another child after three years' cod-liver oil therapy. The previously soft carious tissue had then become hard and the section demonstrates the defensive process in the form of well-calcified secondary dentine.

increase the vitamin D and calcium intake, the latter preferably in the form of milk; this is especially important for pregnant women, infants and children[1].

When we consider how vitamin D produces these effects we are in an atmosphere of pure surmise. The quantities necessary are amazingly small. For instance, it is probable that 500 to 1,000 international units of vitamin D given daily from birth to adolescence would produce perfectly formed bones and teeth if the food was otherwise reasonably good. Now there are 40,000 international units in 1 mg. of calciferol (vitamin D_2), so the necessary daily amount would be $\frac{1}{50}$ to $\frac{1}{10}$ mg., say about 8 mg. a year for the first 15 years, and perhaps a total of $\frac{1}{2}$ gram for the normal life-span of three-score years and ten. In an experiment on a dog the effect of 7,000 international units of vitamin D_2 ($\frac{1}{6}$ mg.) taken over a period of 7 days was to convert a daily negative calcium balance into a markedly positive one. We are obviously at the level of powerful enzymic action. If, as seems probable, calcium and phosphorus metabolism involves the formation of calcium hexosephosphate, it may be surmised that vitamin D has some controlling influence over phosphatase activity in relation to calcification.

The functions of vitamin D in the body are best understood by a study of the conditions resulting from its absence or deficiency, especially during infancy and childhood. With such a

[1]It is essential that vitamin D preparations, and especially cod-liver oil, should be carefully stored. A fact which is not always appreciated is that they tend to lose their potency under certain conditions, including exposure to light and air.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

deficiency the muscles are flabby, the growing bones are relatively soft and bent (figure 1), and the teeth forming at the time are badly calcified and liable to decay (figure 2 (*b*, *c*, and *d*)). (In an examination of 1,300 6-year-old school children in 1929, none was found to have a full set of perfectly formed teeth, and only 4·7 per cent. were free from caries.) This deficiency in early life is reflected in the bent legs and stunted growth of many adults and in the toothless mouths of thousands of middle-aged people. A more serious, but less obvious, result is the badly formed pelvic bones (contracted pelvis) which later so often interfere with normal childbirth. In some large cities where rickets used to be very prevalent, the Caesarean operation is common and mishaps to mother and infant due to contracted pelvis are still abnormally high. A deficiency of vitamin D in adult life can also produce serious results, especially during pregnancy, and these become more prominent in post-war periods and during times of great food restriction.

There is one great difference between calcification processes in bones and teeth which needs emphasis. During the period of growth there is a constant absorption and redeposition of bone tissues, whereas once a tooth is formed it cannot be radically changed. If an infant or child develops bone deformity owing to a deficiency of vitamin D, the old operation of osteotomy, which consists of breaking and resetting the bones, is no longer necessary provided the child is growing, since the condition can be remedied by adding the vitamin to a good general diet, though it may take several years of this therapy to straighten the legs. If, on the other hand, dental structure is bad at any period of development, the part formed at that time will remain bad, although it has been shown in dogs that the addition of vitamin D or cod-liver oil to the diet will cause any later-formed tissue to be well calcified. This is illustrated by figure 6.

Examination of large numbers of deciduous and permanent human teeth between the years 1921 and 1934 showed that, by whatever method they were examined—*in situ*, macroscopically after shedding or extraction, or histologically—not more than 10 per cent. of the deciduous and 7 per cent. of the permanent teeth were of really good structure according to the standards used. All the rest showed some degree of defect, as illustrated in figures 2 and 7. Since the structure of our teeth is influenced by fat-soluble vitamins, especially vitamin D, we cannot afford to allow such vitamins to be deficient at any time during the period of dental development.

While it would be wrong to give the impression that if teeth were perfectly formed all caries would cease, it can be stated quite definitely that there is a real relationship between tooth structure and susceptibility to caries, poorly formed teeth being much more likely to suffer decay than well-formed teeth. For instance, in the collections of children's teeth referred to above it was found that there was no caries in 78 per cent. of the well-calcified teeth, whereas only 6 per cent. of those with very poor structure were free from decay. Conversely, caries was extensive in only 7·5 per cent. of the well-formed as compared with 74 per cent. of the very badly formed teeth.

When a tooth is attacked by caries, it tries to defend itself against the invading micro-organisms if conditions are favourable. Here again vitamin D is called for, and if sufficient be provided, together with plenty of calcium and phosphorus in the form of milk, the attacked tooth may build up a barrier of new dentine (secondary dentine) as a defence; the progress of the disease may thus be arrested and the tooth may become 'healed.' An example of 'healed' caries can be seen in figure 8 (*c*). Thus a sufficiency of vitamin D will not only act as a main factor in procuring perfectly formed teeth, but will also help teeth attacked by caries to defend themselves. Again, how this is done remains to be discovered.

Although it has been shown above that vitamin D is not the only factor to be considered in dental and bone structure, it is probably the main factor and is certainly the one most likely to be deficient in the diet of people in temperate zones.

Recent work on dogs has shown that vitamin A, as well as vitamin D, plays a part in bone and tooth structure, but it has quite a different function from that of vitamin D. As regards bones, whereas the effect of vitamin D is to harden them, vitamin A regulates the activity of bone-forming cells; in its absence they become too active, and overgrown bones are produced. In the case of the teeth the effects of a deficiency of vitamin A are less obvious, but owing to overgrowth of the cementum the roots tend to become stunted. There are undoubtedly nutritional factors other than vitamins D and A, calcium, phosphorus, and phytic acid concerned in the formation of bones and teeth and in the protection of the teeth against decay, but, except as regards this latter instance, the back of the problem has probably been broken.

The war has caused a greatly increased interest

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

in human nutrition, and many nutritional surveys are being made. The general result has not shaken the view that vitamin D is still the greatest single deficiency in the British diet. In the period between the last war and this one there was a definite improvement in the growing population, especially in industrial areas, but there is reason to believe that during the present war rickets is again on the increase. The Government has recently, however, taken steps to remedy this by supplying more cheap or free milk to the young, by adding calcium carbonate to the national flour to antagonize the additional phytic acid it contains, by adding vitamins D and A to all margarine, and by making cod-liver oil and other vitamin D preparations easily available. With our present knowledge of nutrition, and especially of the factors controlling bone and tooth formation, it ought to be possible to ensure for coming generations good hard bones and white, shiny teeth comparatively free from decay and regularly arranged in well-developed jaws.

Book reviews

THE PHILOSOPHY OF A SCIENTIST

Physics and Philosophy, *by Sir James Jeans, O.M. Pp. vii + 222. Cambridge University Press, London.* 1942. 8*s.* 6*d. net.*

Some of the most original and valuable contributions made to philosophy in this century have been due to men who began life as mathematicians or mathematical physicists—A. N. Whitehead, Bertrand Russell, J. H. Jeans, A. S. Eddington, and H. Jeffreys, all of whom were products of the Cambridge mathematical tripos; and this is natural enough: for it is no longer possible to philosophize about space, time, and matter without understanding relativity and quantum-mechanics. The prospect that in the future the typical occupant of a university chair of philosophy will be an ex-mathematician is brought still nearer by this profoundly interesting little volume.

Sir James considers, in the light of modern physical concepts, the rival doctrines of materialism and subjective idealism, and shows that Berkeley's argument, though invalid for the purpose for which he intended it, can be used to prove that mind and matter have something in common. He then compares the duality of mind and matter with the duality of waves and particles in quantum-mechanics; as he points out, the ingredients of the particle-picture are particles existing in physical space, while the ingredients of the wave-picture, which are waves of knowledge, are mental constructs existing in conceptual space: the ingredients of the particle-picture are material, those of the wave-picture mental. Since we find that we can best understand the course of events in terms of waves of knowledge, there is a certain presumption that reality and knowledge are similar in their natures or, in other words, that reality is wholly mental. In any case, the two members of the new dualism—waves and particles—are not antagonistic or mutually exclusive as mind and matter were: they fit harmoniously into a unity, the waves controlling the particles: in the old terminology, the mental controls the material.

The discussion of the consequences of Heisenberg's uncertainty-principle may also be specially commended.

E.T.W.

SPECTROSCOPY AND COMBUSTION

Spectroscopy and Combustion Theory, *by A. G. Gaydon. Pp. x + 191. Chapman & Hall Limited, London.* 1942. 17*s.* 6*d. net.*

In the analysis and systematization of band-spectra on the basis of the quantum theory, many band systems produced in flames were assigned to emitting radicals such as CH, NH, OH, C_2, and CN, whose existence, though long suspected, had not previously been satisfactorily established, and the electronic, vibrational and rotational states of these emitters in flames were completely determined. Later studies have led to an understanding of the presence and roles of these intermediate products in combustion processes and have yielded much new information on flame reactions.

Dr. Gaydon's book deals entirely with these spectroscopic investigations. It opens with an elementary account of the theory of molecular spectra and of the conditions under which band systems appear in emission, and leads, through brief descriptions of several types of flame spectra, to applications of spectroscopy to derivations of lifetimes of activated molecules and dissociation energies, the after-burning of carbon monoxide and the kinetics of the combustion process.

A 20 pp. appendix giving numerical data and other information on molecular spectra and energy levels in flames, two plates of excellently reproduced flame spectrograms, and an adequate index, add considerably to the usefulness of a monograph which is unreservedly recommended to all who are interested in or engaged on combustion problems.

W.J.

A CONCISE HANDBOOK TO MILITARY 'GASES'

War Gases: their Identification and Decontamination, *by Morris B. Jacobs. Pp.* 180. *Interscience Publishers Inc., New York; Imperia Book Company Limited, London.* 1942. $3 *net.*

This is an excellent compendium for gas identification officers, war gas chemists, decontamination officers, public health officers, and all others interested in chemical warfare. It is not so detailed or comprehensive as previous books on the subject, such as Prentiss and Sartori, but it presents in simple, concise, and systematic manner the essential information regarding the

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

identification of the various types of toxic gases and the methods for decontaminating materials of all kinds polluted thereby. Its exact contents are displayed in the chapter headings: Classification of the Chemical Agents; Physical Characteristics and Physiological Response of the War Gases; Effect of War Gases on Materials, Water, an dFood: Sampling; Scheme of Analysis; Detection and Determination of Arsenic; Confirmatory Tests; Decontamination.

The main facts and procedures have been collected from British A.R.P. publications and other official sources. The volume contains little that is new, but it is accurate and easy to read and to understand. A great deal of the more important material is admirably summarized in tabular form, but it is unfortunate that Table III in the Appendix (Order of Toxicity of the War Gases) conflicts, in many cases, with the data in preceding tables and omits phosgene altogether.

JAMES KENDALL

A SYNTHESIS OF MORPHOLOGY AND BIOCHEMISTRY

Biochemistry and Morphogenesis, *by Joseph Needham. Pp. xvi* + 787. *Cambridge University Press, London.* 1942. 52*s.* 6*d. net.*

There are signs that, after the age of specialization which was the intellectual accompaniment of the later developments of *laissez faire*, we are now returning to the broad synthetic sweep which has been the usual aim of civilized man. Dr Needham's monumental work is one of the signs of this return. In it he takes the data of two biological disciplines which up till quite recently have been pursued in isolation and succeeds to a remarkable degree in synthesizing them in a mutually illuminating fusion. Both are active growing points of biological science. Biochemistry is rapidly unravelling the chemical processes underlying vital activity: experimental embryology or *Entwicklungsmechanik* is formulating the empirical principles of animal and plant development. The two are on different planes of study. Needham has succeeded in building staircases connecting the two sets of levels.

In a brief review, all that can be done is to pick out a few high lights. Perhaps the most spectacular is the way in which the cancer problem is illuminated. In the first place, the chief carcinogenic substances are closely related chemically to the substance which acts as evocator in the vertebrate organizer (as well as to the sex hormones). Secondly, the evocator exists in a masked form in all parts of the embryo, probably in combination with a specific protein, and its activity in the organizer region is due to this combination being here broken, through some peculiarity of metabolism. A formal explanation of cancer, superseding the idea of 'embryonic rests' and furnishing a more satisfactory alternative to the virus theory, is provided by the idea that a masked carcinogen is similarly liberated under certain abnormal conditions of metabolism. Much work remains to be done, but it is clear that a new and hopeful approach is provided.

Similarly the biochemical facts, largely elicited by the Needham school, as to the nature and mode of working of the evocator substance, and its cooperation with the chemical 'competence' of the reacting tissue and with the individuation field of the whole embryo, are throwing light on numerous problems of normal development and regeneration, and on the mode of action of hormones and of genes.

The gradual clarification of the idea of the developmental field, an empirical notion entirely derived from the facts of *Entwicklungsmechanik*, is in its turn illuminating the chemical study of growth, while from the opposite side our knowledge of liquid crystals is helping us to understand and to define the properties of developmental fields.

It would be possible to continue indefinitely. Here we can only say that all serious students of biology, whether biochemist, embryologist, physiologist, geneticist, cancer worker, growth specialist, or general evolutionist, will find valuable new light on their old problems in Needham's pages. The book is exhaustive and heavily documented, and contains numerous fascinating excursions into collateral issues. The present reviewer has only one regret—that Needham has deliberately excluded the field of invertebrate regeneration from his survey.

Biochemistry and Morphogenesis is more than a successor to Needham's previous great work *Chemical Embryology;* for while that was essentially a survey, this is essentially a creative synthesis. It is one of the most important contributions to biology made in the present century, and will secure for its author a permanent place in the history of science. JULIAN HUXLEY

ABSORPTION SPECTRA IN BIOCHEMISTRY

The Application of Absorption Spectra to the Study of Vitamins, Hormones, and Coenzymes, *by R. A. Morton. Pp.* 226. *Adam Hilger Limited, London. Second edition,* 1942. 28*s. net.*

In the application of spectroscopy to biochemical problems, far the most important advance was the development of the ultra-violet spectroscope and spectrophotometer. Among compounds of biological interest there are many more uncoloured than coloured, but a high proportion of those that are completely transparent to visual light have been found to show characteristic absorption spectra in the ultra-violet region. Measurement of the wavelength and intensity of this 'invisible colour' is now a commonplace operation, even in many routine industrial laboratories, serving as a highly accurate analytical method, and has played at least as great a part as visual spectroscopy in helping to establish the constitution and investigate the metabolic roles of many of the substances discussed in Dr Morton's admirable monograph.

This edition is nearly four times as long as the first. It is impossible here even to begin to detail the many advances that have been recorded during the intervening seven years, but it is symptomatic that two of the chapters in the new edition, those on 'Vitamin E and Anti-oxidants' and 'Vitamin K,' are represented in the original edition by just over two pages about vitamin E; the existence of vitamin K was hardly recognized in 1935. Other advances of which Dr Morton takes cognizance are our knowledge of the interrelationship between certain water-soluble vitamins and enzyme systems, and the clear establishment of a structural connection between the steroid hormones, the anti-rachitic vitamins, and the active substances of the adrenal cortex.

In order to make clear the part played by spectroscopic technique in helping to establish the progress recorded by Dr Morton, he has had to discuss in considerable detail the chemistry of all the fat-soluble vitamins (A, D, E, and K), of many water-soluble vitamins [C, B_1 (aneurine), riboflavin, nicotinic acid, pyridoxin (B_6)], as well as some of the borderline cases such as vitamins P and H, and has also devoted a chapter to purine and pyrimidine derivatives and a few

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

pages to the spectroscopy of some amino-acids. The tenth and last chapter, on 'Enzymes and Coenzymes,' gives a concise but extremely useful summary of our knowledge of several of the most important cellular enzyme systems. The book thoroughly deserves a wide circulation amongst all who are concerned with the chemical aspects of fundamental cellular processes in animal and plant organisms.

A. L. BACHARACH

A QUANTITATIVE STUDY OF PLANT REPRODUCTIVITY

The Reproductive Capacity of Plants, *by E. J. Salisbury. Pp. xi + 244, with 7 plates and 35 text figures. G. Bell & Sons Limited, London.* 1942. 30*s. net.*

This remarkable book is the first extensive quantitative account of the reproductive capacity of flowering plants. Reproductive capacity is determined by seed output and viability and, as both are highly variable, many counts are necessary. The labour of gathering the data for a large number of British plants must have been heroic. The main object of the book is to provide a foundation for conclusions as to the effect of reproductive capacity on survival and dispersal, and this theme is treated from various angles. There are accounts of special systematic and ecological groups, such as the gentians and St. John's worts, and the saprophytes and parasites. The relation of seed size to type of community, open or closed, is discussed. As between different species of the same genus, a case is made for the view that comparative rarity goes along with lower reproductive capacity. A final chapter on vegetative propagation is of special interest and includes several valuable figures. Here Professor Salisbury's happy gift of picking significant and striking facts from his extensive observations in field and garden is notably evident. The data might have been presented in a more condensed form without impairing the value of an important work.

M. SKENE

THE STUDY OF SOCIETY

Social Structure, *by H. A. Mess. Pp.* 130. *George Allen & Unwin Limited, London.* 1941. 6*s. net.*

All books popularizing social study are welcome today, when clearly we must obtain an increased understanding of those processes which have brought our civilization into such violent disarray. There has been a flow of books about the social sciences, without (as yet) one really complete and coherent analysis either of the latest knowledge, or of the best available methods for its scientific study. In the meanwhile, Dr Mess has contributed another to the growing list of useful little volumes.

Social Structure is well written, interestingly arranged, stimulating. Its main weakness is one common to most of these sociological primers: a lack of factual illustration based on objective study. Dr Mess relies on generalizations which are often subjective and unsupported by reliable evidence. He frankly finds himself faced with terminological difficulties of verbal definition; until we have a much closer analysis of what actually happens in human affairs we are bound to use academically imposed categories and classifications. He himself gets caught up in these—for instance when discussing 'Community' (p. 78) or distinguishing between intellectual aspects and emotional associations (p. 119). The result is sometimes very confusing.

T.H.

SHORTER NOTICES

Hydrogen Ions, *by Hubert T. S. Britton. 2 vols., pp. xix + 420 and xix + 443. Chapman & Hall Limited, London. Third edition,* 1942. 36*s. net each volume.*

This well-known book, first published in 1929, rapidly established itself as the standard work on the subject, and a second edition was called for in 1932. For the present edition, published in two volumes, the author has revised the whole text and made substantial additions which will greatly increase its usefulness. We are particularly glad to note the inclusion of a chapter on Redox potentials, the symbol *r*H, and the use of Redox indicators. The importance of *p*H control in a wide variety of applied chemical fields is very clearly discussed, as is also relevant modern work in inorganic and analytical chemistry. Professor Britton has written a book of distinction.

The Structure of Steel simply Explained, *by E. Gregory and E. N. Simons. Pp. xv + 140. Blackie & Son Limited, London. Second edition,* 1942. 5*s. net.*

An interesting and plainly written little book which describes the structure of steel with a minimum of technical phraseology. The general scientific reader who wants to know something about those numerous and diverse metallic substances subsumed under the single title of 'steel' could not do better than follow the lucid story here told by Dr Gregory and Mr Simons.

War against Disease, *by Milton Silverman. Pp.* 284. *Michael Joseph Limited, London.* 1942. 12*s.* 6*d. net.*

Popular scientific books often fall between two stools—if they are popular they are frequently inaccurate scientifically, while scientific precision is liable to limit their popular appeal. Mr Silverman's book—the sub-title of which is 'Miracles of Modern Medicine'—suffers from neither defect. It tells in a vivid and dramatic manner of the discovery of quinine, cocaine, aspirin, the vitamins, sulphanilamide, etc., and the author has obviously been at great pains to verify his facts. The style of the book has necessitated the introduction of imaginary conversations, but this is quite a legitimate device. We recommend the book to scientists and laymen alike; it should certainly be in every public library.

Twins and Super-twins, *by H. H. Newman. Pp.* 164, *with* 19 *illustrations. Hutchinson & Company (Publishers) Limited, London.* 1942. 10*s.* 6*d. net.*

Professor Newman, who for over a quarter of a century has made a special study of multiple human births, here attempts to give systematic and reliable answers to such questions as 'What causes twins?' 'Are twins likely to be sterile?' 'How many kinds of twins, triplets, etc., are there?' 'Are twins desirable?' He has collected a great deal of information on the subject and his book is worth reading.

Mathematics: its Magic and Mastery, *by Aaron Bakst. Pp. xiv + 790. Chapman & Hall Limited, London.* 1941. 21*s. net.*

This book, first published in the United States, compares not unfavourably with *Mathematics for the Million.* It is a skilful effort to make the fundamentals of mathematics interesting and even amusing to the general reader, by presenting the science in the light of its versatility in the various fields of human endeavour. With the proviso that the reader must keep his wits constantly on the alert, the effort must be regarded as very successful. An excellent gift-book for intelligent young people.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

ENDEAVOUR
Digitized by Arya Samaj Foundation Chennai and eGangotri

A quarterly review designed to record the progress
of the sciences in the service of mankind

VOLUME II JULY 1943 NUMBER 7

Science and the post-war world

The United Nations have declared their resolution to create an enduring peace. Success in this high resolve will depend to an important degree upon the adoption of the scientific attitude of mind—that is, to put it bluntly, upon the adoption of habits of thought and action still foreign to a large part of the population. People will be ready enough to accept the practical results of science—perhaps to praise it for the material advantages it brings, and certainly to blame it for any real or fancied shortcomings. They will buy from the scientific shop-window and shelves, because that is attractive and easy. It is harder to acquire a new vision. Yet it is the new vision that matters. We have seen the fruits of the old.

To some of the difficulties that retard a general appreciation of the nature of science, and consequently a wider adoption of its methods and outlook, reference has already been made in ENDEAVOUR. There is, however, a further difficulty which, since it has an unmistakable bearing upon future harmonious development, deserves serious consideration. This is the false and mischievous idea, frequently expressed and still more often tacitly held, that science is something inimical, or at best indifferent, to the philosophical 'values' which in varying degrees represent man's epitomized estimate of the worthwhile in life. Though it would seem plainly absurd to maintain that any product of the human intellect could thus be isolated, there is no doubt that science is commonly regarded as possessed of a non-human, even inhuman, frigidity which sharply differentiates it from other experience—'coldly scientific' has become a cliché. Such an opinion, widespread though it now is, is of comparatively recent origin. As Mr. Ian Rawlins indicates in his article in the present issue, it was absent from classical Greek thought, where the arts and sciences reached an intimacy in which each partner was willing to contribute what it could to the common culture; and it would scarcely have occurred to Newton or to his successors of the eighteenth century—one of whom, Priestley, goes indeed so far as to classify the pleasures derivable from scientific investigation as but one degree removed from those of sense.

Historically, the basis for the judgment of science as something cold and impersonal, *sui generis*, to be used for material gain but also to be mistrusted or contemned, is to be found in the enormous scientific advances of the nineteenth century, with their often squalid commercial accompaniments, and in the over-confidence of many scientists, which provoked a natural reaction. Science was held responsible for undesirable economic and political phenomena which it had undeniably rendered possible, nor was it forgiven for bringing about the overthrow of cherished superstitions. The controversies of that time now seem stale, flat, and unprofitable; but from them there emerged the fiction of the 'non-humanity' of science which scientists, anxious no doubt to leave the lists for the laboratory, accepted as a *modus vivendi*. The fiction has now become so firmly entrenched among the general public as almost to be accepted as axiomatic; and though no scientist would subscribe to it, few but a handful of mathematical philosophers have made efforts to combat it.

It may require an Eddington or a Whitehead to grapple with the fundamentals of the situation, but all scientists, and especially those who teach others, can make their contribution: first by the disavowal of extravagant claims and second by vigorous insistence upon legitimate ones. Science, for instance, does not pretend to reveal 'eternal verities,' but it does provide an ever-increasing store of substantiated and communicable knowledge. And science is as intimately concerned

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

with the philosophical values as is any other offshoot of the human mind: it is simply another facet of the same crystal. Admittedly the concern of science is most obviously with truth, for 'the truth, the whole truth, and nothing but the truth' is an aim more unswervingly pursued and more frequently attained in laboratories than in courts of justice. But while critics may admit scientific honesty of thought, they deny to science any emotional value; and it is here that the difficulty lies. For if science continues to be regarded as merely a soulless search for verifiable knowledge, it can never form a warm inspiration for the community as a whole, or even win its confidence. There will, in short, be a lack of harmony between the body scientific and the public—a condition of affairs long apparent, and one which will inevitably deteriorate with increasing complexity of scientific progress unless measures are taken to check and overcome it.

Scientists who are also musicians—and it is significant that musical appreciation and execution are very frequently coupled with scientific ability—know that the Fifth Symphony is as much a triumph of scientific method as of art; and that conversely great scientific achievements such as the *Principia* are also artistic masterpieces, infused with a kindred inspiration. Unfortunately, while appreciation of the scientific aspects of music and painting is unnecessary to the reception of their emotional appeal, or at least to the reception of much of this appeal, the artistry of science cannot awaken a similar response in the untutored mind. That is the core of the problem—a hard core, but not irresolvable. The non-scientific public will never be able fully to understand the technical background of science, but with proper guidance and instruction they could be brought to understand that science is no Ishmael. With that comprehension would come a trust in science of good hope for the world. As long as men mistrust or misprize science, or regard it simply as a modern miracle-monger, they will not allow it to exercise its full beneficence. When they feel that here is no stranger in their midst, that Bohr and Einstein are fellow-artists with Bach and Botticelli, that in fact science, in spite of the ordered restraint characteristic of its method, is suffused with human imagination and aspiration, then we shall have a promising guarantee of enduring peace; for with the opportunity that such sympathetic insight would provide, science could amply ensure 'freedom from want' and could go far to ensure 'freedom from fear.'

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

LAVOISIER AND CONTEMPORARY BRITISH CHEMISTRY

From Douglas McKie, Ph.D., D.Sc.

In other times than these, the bicentenary on 26th August next of the birth of Lavoisier would no doubt have been widely celebrated. Here in Britain, even in the grim shadow of war, we may recall on this occasion the part played by our fellow-countrymen in the chemical revolution effected by the imaginative genius of one of the greatest sons of France.

When Lavoisier began his work on combustion in 1772–73, he recorded his indebtedness to Black, Priestley, and Cavendish, among others; and he noted that the 'air' contained in bodies had not been studied by French chemists. 'The French chemists alone,' he wrote, 'seem not to take any part in these important inquiries.' Oddly enough, after Lavoisier's work was completed, Fourcroy spoke of the new theory as 'la théorie des chimistes français,' which drew from Lavoisier the indignant protest: 'Cette théorie n'est pas, comme je l'entends dire, celle des chimistes français, elle est la mienne: c'est une propriété que je réclame auprès de mes contemporains et de la postérité.' Historians have always admitted the justice of this claim.

Lavoisier first repeated Black's experiments on the mild alkalis and wondered whether the 'air' that was active in the calcination of metals was Black's 'fixed air.' Late in 1774 Priestley gave him the clue to the whole problem by telling him of the curious properties of the 'air' that he had obtained from *mercurius calcinatus per se* and from red lead. Thereafter, Lavoisier was led on from Priestley's experiments to the new theory of combustion, respiration, and calcination, which he

(*Continued on page* 98)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Enzymes and their mode of action

Digitized by Arya Samaj Foundation Chennai and eGangotri

J. H. QUASTEL

During the last few years there has been considerable progress in the investigation of those complex, and for long mysterious, biological catalysts known as enzymes. One of the foremost authorities in this field, Dr J. H. Quastel, here offers a review of some of the principal recent discoveries relating to the constitution of enzymes and how they work.

Enzymes are indispensable for the changes proceeding in the living cell. Without them matter would be lifeless. No process associated with cellular activity, whether it be the growth and proliferation of the lowliest of organisms or the functioning of the most highly organized of living structures, such as the central nervous system, can be imagined taking place without the participation of enzymic reactions. In death, enzymes are as active as in life, though their organization is completely altered. The autolytic changes occurring in the cell, which through unfavourable environmental circumstances can no longer survive and proliferate, are controlled by enzymes which themselves ultimately break down and lose their activities. No aspect of the chemistry of living matter, whether it refers to such diverse phenomena as the luminescence of bacteria, the bacterial fixation of atmospheric nitrogen, the breakdown of cellulose in the animal gut, the decomposition of proteins, fatty acids, and sugars in all living tissues, the building up of hormones, and the synthesis of vitamins in the plant or in the body, may be regarded as complete without due regard to the controlling influence of enzymes.

Intensive investigation into the mechanism of formation of common biological products such as alcohol and lactic acid has revealed complex systems of chemical operations each of which is characterized by the controlling activity of a specific cell catalyst or enzyme. It is this control of an endless variety of chemical changes by, for the most part, highly specific cell agencies, which forms the distinguishing feature of the course of biochemical events.

Owing to the diversity of the chemical operations involved in the breakdown of a molecule like glucose, which is attacked by so very many types of living cell (bacteria, animal and plant tissues), and to the fact that different cells have different sets of enzymic equipments, the products of breakdown of glucose, for example, vary enormously. It may be converted into lactic acid, or alcohol, or fumaric acid, or citric acid, or acetone, or starch, etc., according to the biological conditions or to the types of cell involved. These processes are pointers to the various types of enzymic agencies which, for the most part, are indispensable for the life of the cells accomplishing the processes. The enzymic processes indicate the nature of the constitutions of these cells, but much further work will be required to ascertain what parts the enzymes in question play in maintaining the lives of the cells themselves.

CONSTITUTION OF ENZYMES

Enzymes are colloidal organic catalysts synthesized, so far, only in the living cell. Most early workers considered enzymes to be proteins, without any direct evidence in support of their view. Willstätter's work on enzyme purification showed how impure were early preparations of enzymes, but his most active preparations were still very dilute and gave negative tests for proteins and carbohydrates. This led to the conclusion that his purified enzymes were neither proteins nor carbohydrates—a conclusion quite unjustified, since there was no means of ascertaining the actual activity of the enzymes. Northrop has pointed out that bacteriophage, which brings about lysis of certain bacterial cells (though it is not regarded as an enzyme in the usual sense of the word), will show its activity in a solution containing about 10^{-15} gm. per millilitre, i.e. one part in one thousand million million parts of water. This solution, of course, would not respond to any of the known tests for chemical compounds, and erroneous conclusions might be deduced from such negative evidence.

Recently, however, many enzymes have been obtained in a crystalline state, for example urease (Sumner, 1926), pepsin (Northrop, 1930), trypsin (Northrop and Kunitz, 1932), carboxypeptidase (Anson, 1935), amylase, papain, and lysozyme.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Enzymes involved in oxidative processes have also been crystallized, e.g. 'yellow' respiratory enzyme (Warburg, 1938), catalase (Sumner and Dounce, 1937), and lactic dehydrogenase (Straub).

In all cases examined so far the purified crystalline enzymes have proved to have the properties of proteins. The molecular weights of a number of these enzymes have been ascertained by the methods now in vogue for the study of proteins. Some of the results obtained are shown in Table 1, which also indicates the molecular weights of proteins having no known enzymic action. Most of the evidence points to enzymes having structures allied to, if not identical with, the proteins. As will be shown later, the catalytic activities of many enzymes depend not only on the chemical make-up of the proteins but on the constitution

TABLE I

MOLECULAR WEIGHTS OF PROTEINS

Enzymes	Catalase	250,000
	Urease	480,000
	Pepsin	35,000 (possibly 70,000)
	Trypsin	34,000
	Bacteriophage	about 500,000 (higher values also obtained)
	Insulin	41,000
	Lactalbumin	17,000
	Haemoglobin (horse)	68,000
	Serum albumin (horse)	70,000
	Serum globulin (horse)	167,000
	Thymoglobulin (pig)	630,000
	Anti-pneumococcus serum globulin (man)	195,000
	Anti-pneumococcus serum globulin (rabbit)	157,000
	Anti-pneumococcus serum globulin (horse)	920,000

of certain substances, of relatively low molecular weights and often termed prosthetic groups, which combine specifically with the proteins. Other enzymes, however, notably the hydrolytic enzymes, have no known prosthetic groups, and presumably their activities are conferred solely by the special arrangement of the amino-acids in the proteins. We are quite unaware of the nature of this arrangement, which may not, however, defy investigation for very long, since it is possible to prepare proteins which are very closely allied chemically to the active enzymes but which are catalytically inert. Only small chemical changes may be involved in the transformation of an active protein into an inactive one and vice versa.

REVERSIBILITY OF ENZYME ACTION

A most important property of an enzyme is that it can secure reversibility of the reaction which it controls. A hydrolytic enzyme will not only split a substance into products by the addition of the elements of water, but is capable of building up the substance from these products with the elimination of water. It is doubtless this property of an enzyme which is partly responsible for the synthetic operations of the cell, and therefore ultimately for growth and proliferation. The reversibility of action of such hydrolytic enzymes as maltase, emulsin, and urease is well known. It is possible to show that enzymes—oxidizing as well as hydrolytic—may act as perfect catalysts.

In presence of the enzyme succinic dehydrogenase, which is widespread and important in cellular respiration, the succinate ion is oxidized by certain dyestuffs to fumarate. The latter ion is reduced to succinate in presence of the same enzyme by the leuco dyestuffs. An equilibrium between the reacting substances is established by means of the enzyme according to the following equation:

$$\begin{matrix} CH_2\cdot COO^- \\ | \\ CH_2\cdot COO^- \end{matrix} + D \rightleftharpoons \begin{matrix} CH\cdot COO^- \\ \| \\ CH\cdot COO^- \end{matrix} + DH_2$$

succinate — dyestuff (e.g. methylene blue) — fumarate — reduced dye (e.g. leuco-methylene blue)

The equilibrium point, which was shown to be independent of the amount of enzyme employed, was first determined colorimetrically in presence of a suspension of bacteria, and was in fact the first of its kind to be established with oxidizing enzymes. It was soon discovered that the same equilibrium was established by the enzyme obtained from entirely different biological sources, potentiometric measurements being made in these cases. Finally it was demonstrated that the equilibrium point was exactly that which could be predicted from the thermochemical data of the energy changes involved in the conversion of succinic acid into fumaric acid and hydrogen ions. Table 2 shows how the free energy changes calculated from the experimental data obtained with different preparations of the enzyme agree with those calculated from thermal data only. The agreement between the experimental values, obtained under widely different biological conditions, is extraordinarily good, and proves that succinic dehydrogenase, the enzyme controlling the reaction, acts as a perfect catalyst.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

TABLE 2

Succinate$^{=}$ + Dyestuff $\rightleftharpoons$ Fumarate$^{=}$ + Leuco dyestuff		
Thermal data: Succinate$^{=}$ $\rightleftharpoons$ Fumarate$^{=}$ + $2H^+$ + 2 (e). $-\Delta F^1 = -20{,}450$ calories (25° C)		
Experimental data:		
Source of Enzyme	*Method used*	$-\Delta F$ (25° C) *calculated from observed Equilibrium Point*
Suspension of bacteria (*B. coli*)	Colorimetric	− 20,180
Horse skeletal muscle	Colorimetric	− 19,140
Horse skeletal muscle	Potentiometric	− 20,100
Beef heart ..	Potentiometric	− 20,140
Beef diaphragm..	Potentiometric	− 20,140

Other reactions involving fumarate, and governed by separate enzymes, are:

$$l\text{-aspartate} \xrightleftharpoons{\textit{aspartase}} \text{fumarate} + NH_3$$

$$l\text{-malate} \xrightleftharpoons{\textit{fumarase}} \text{fumarate} + H_2O$$

The free energy changes calculated from the experimentally determined equilibrium points agree with those predicted from the thermal data.

These reactions afford examples of the activities of three distinct enzymes—succinic dehydrogenase, aspartase, and fumarase—all acting on a common substrate, viz. fumarate. Even molecular hydrogen is attacked in different ways by different enzymes. Thus the bacterial enzyme hydrogenlyase controls the following reversible reaction: $H_2 + CO_2 \rightleftharpoons H{\cdot}COOH$, whilst the enzyme hydrogenase, also found in bacteria, catalyses the reaction $H_2 \rightleftharpoons 2H^+ + 2\ (e)$. Many enzymic reactions proceed so far in one direction that the reverse reaction appears not to take place. Cases in point are the breakdown of hydrogen peroxide to oxygen and water by catalase and the oxidation of acetaldehyde to acetic acid by aldehyde oxidase.

SPECIFICITY OF ENZYME ACTION

Enzyme action varies from an apparently absolute specificity to what may be termed a group specificity, where a whole series of molecules belonging to a defined chemical group is attacked by one enzyme. For example, the enzyme formic dehydrogenase acts (so far as is known) only upon formic acid, catalysing its oxidation to carbon dioxide and water. This is absolute specificity; yet since the enzyme acts as a catalyst it should be capable of accomplishing the reverse reaction, i.e. the reduction of carbon dioxide to formic acid. This has not yet been demonstrated, and the enzyme is distinct from hydrogenlyase, which accomplishes the reduction of carbon dioxide to formic acid by molecular hydrogen. Choline dehydrogenase, another oxidizing enzyme, has a restricted field of action, for it will bring about the oxidation of choline, $^{+}N(CH_3)_3{\cdot}CH_2{\cdot}CH_2{\cdot}OH$, and of arsenocholine, $^{+}As(CH_3)_3{\cdot}CH_2{\cdot}CH_2{\cdot}OH$, the corresponding aldehydes being formed; but it will not act on colamine, $NH_2{\cdot}CH_2{\cdot}CH_2{\cdot}OH$, or on ethyl alcohol, $CH_3{\cdot}CH_2{\cdot}OH$. It is the exception, however, rather than the rule, for the activity of an enzyme to be restricted to one or two substrates. Sulphatase brings about the hydrolysis of a large variety of sulphuric acid esters, including those of phenols, naphthols, and diphenols. But the sulphuric acid esters of alkyls, borneol, and mandelic acid are not attacked. The many enzymes which hydrolyse proteins, polypeptides and dipeptides have each limited fields of attack. Thus a proteolytic enzyme named amino-peptidase requires the presence in its substrate not only of the peptide linkage —CO—NH— which is hydrolysed, but of an amino group in close proximity to the linkage. Again, another enzyme termed carboxypeptidase requires in the substrate a carboxyl group in addition to the peptide bond which is attacked. When proteinases hydrolyse, or synthesize, a peptide bond, they require, near the point of action, another peptide bond. In fact, the class of enzymes comprising the aminopeptidases and carboxypeptidases acts upon terminal peptide bonds in a polypeptide; hence Bergmann has called them exopeptidases. The other class of enzymes, containing the well-known enzymes trypsin and pepsin, attacks centrally located peptide bonds (as well as terminal ones); they have been called endopeptidases. The study of the specificity of proteolytic enzymes is exceedingly complicated, for proteins and mixtures of protein degradation products are commonly used as substrates. In such systems synthetic reactions as well as hydrolytic reactions may take place and, as Bergmann points out, may give a misleading picture of the specificities of the enzymes involved.

[1] ΔF expresses a free energy change and is a measure of the maximum external work accomplished under isothermal conditions by a reversible process in passing from its initial to its equilibrium stage.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Most of the well-known enzymes show restricted fields of activity: thus carboxylase attacks a number of molecules of the type RR'CH·CO·COOH, liberating carbon dioxide and the corresponding aldehyde; glyoxalase converts molecules of the type R·CO·CHO into the corresponding acids R·CHOH·COOH by the addition of water; choline esterase hydrolyses many esters of choline but will not hydrolyse the esters of fatty acids; amine oxidase, an oxidizing enzyme, attacks amines $R \cdot CH_2 \cdot NH_2$ to form R·CHO and NH_3, but whereas it acts vigorously on such amines as tyramine and isoamylamine, it will not attack methylamine or ethylamine; and diamine oxidase, another oxidizing enzyme, attacks amines containing two strongly basic groups, ammonia being liberated, but is distinct from amine oxidase or amino-acid oxidase. Examples like these may be multiplied. All lead to the conclusions that a general feature of enzyme action is its restriction of activity to the presence of a particular type of molecular structure in the substrate, and that molecules having this type may be attacked at widely differing velocities. This restriction of the activity of any enzyme to a group of molecules points to the presence in the group of a common structure necessary for the combination of substrate and enzyme.

COMBINATION OF ENZYME WITH SUBSTRATE

It is generally assumed that the first step in enzyme catalysis is the formation between enzyme and substrate of a compound which, after a definite time-interval, decomposes to form the reaction products and the original enzyme. The place of combination with the enzyme is left vacant until another substrate molecule enters the sphere of action, when the cycle of combination and decomposition takes place again. It is useful to accept this view of compound formation and breakdown not only because the kinetics of enzymic change can be interpreted on this basis, but because there is good evidence that compounds between enzyme and substrate do in reality exist. An example of such evidence comes from the facts concerning the protection, by substrates, of their enzymes from inactivation by heat and other agencies. Thus invertase is less sensitive to the inactivating action of heat in presence of its substrate, sucrose. Fumarase is completely protected by its substrates, fumarate and *l*-malate, from the poisoning action of very small quantities of dyestuffs belonging to the Congo Red series. Since neither of these substrates combines with the dyestuffs, it follows that their effects are exerted by combination with the enzyme itself, thereby masking the groups which would otherwise combine with the dyes. A similar phenomenon occurs with urease, whose substrate, urea, protects the enzyme from inactivation by many dyestuffs. Succinic dehydrogenase is also protected by its substrate, succinate, from the inactivating action of oxidized glutathione. Other evidence for the formation of complexes between enzyme and substrate comes from spectroscopic observations on the colour changes which take place under certain conditions when union occurs between catalase or peroxidase and hydrogen peroxide.

ATTACHMENT-GROUPINGS IN THE SUBSTRATE

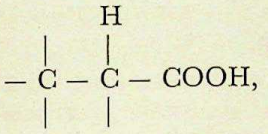
Not only the substrates of an enzyme combine reversibly with the enzyme. Molecules similar in structure to the substrate may also combine with the enzyme, although they do not undergo any subsequent chemical change. Such substances, when mixed with the substrate, compete with it for the enzyme and reduce its effective concentration. For example, in the case of succinic dehydrogenase the following molecules compete with succinic acid for the enzyme: $COOH \cdot CH_2 \cdot COOH$ (malonic acid), $COOH \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot COOH$ (glutaric acid), and $COOH \cdot CH(CH_3) \cdot CH_2 \cdot COOH$ (methylsuccinic acid). Among these molecules, malonic acid has the greatest affinity for the enzyme. This affinity is so high, compared even with that of succinic acid, that malonic acid will displace succinic acid from succinic dehydrogenase and so reduce the velocity of oxidation of succinic acid by its enzyme. The malonic acid itself, although combined with the enzyme, undergoes no chemical change. This effect of malonic acid, in virtually poisoning (in a reversible manner) succinic dehydrogenase, has proved to be a very useful tool in the study of the part played by succinic acid in cellular respiration; for any respiratory system demanding the participation of succinic acid and succinic dehydrogenase can be detected by the drop in respiratory activity taking place on adding malonic acid to the system. This inhibitory action of malonic acid may be seen in an even more striking way. Certain bacteria will proliferate in a medium where the sole source of carbon is provided by succinic acid, the bacteria oxidizing the succinate as a preliminary step to synthesis. If malonate is also present in the

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

medium, the growth of the bacteria is much retarded, as the malonate inhibits the oxidation of the succinate and less carbon becomes available for the needs of the bacteria. Thus malonate acts as an inhibitor of bacterial growth in this system. It is not a cell poison, for it does not act as an inhibitor in systems where a preliminary breakdown of succinate is not necessary to provide the bacteria with carbon for synthesis. Malonate, therefore, can act as a bacterial inhibitor, the inhibition depending on the constitution of the nutritional medium and type of cell involved.

Molecules which combine with succinic dehydrogenase seem to have little or no affinity for other oxidizing enzymes such as lactic and formic dehydrogenases. A certain structure, apparently the form



is necessary for attachment of a substrate to succinic dehydrogenase. Another structure, $-CO\cdot COOH$, is necessary for substrate attachment to lactic dehydrogenase. The purine nucleus is necessary for union of substrates with xanthine oxidase, which can be poisoned by purines not undergoing oxidation by the enzyme. Amine oxidase similarly can be poisoned by amines which combine with it but are not attacked, e.g. phenylisopropylamine (benzedrine), and there is reason to believe that the pharmacological effects of this amine are linked with its poisonous action on the enzyme. Eserine combines reversibly with choline esterase, inhibiting its hydrolytic action on acetyl choline, a molecule of high physiological significance in the functioning of the central nervous system. This effect of eserine is now definitely linked up with its well-known pharmacological behaviour. These results show that substances may affect physiological processes by reason of their possession of a structure allowing them to combine reversibly with certain enzymes, which are thus prevented from exercising their function of decomposing the substrates presented to them at normal rates. This structure may be termed an attachment-grouping, as it is by means of it that combination with the enzyme takes place.

Another example may be given of the manner in which the presence of the attachment-grouping in the substrate molecule may be demonstrated. Urease, as already stated, is protected by urea from the poisonous action of many dyestuffs. Several other substances (which are not true substrates as they are not decomposed by urease) also have protective effects. These are α-amino acids, sarcosine, ethylenediamine, hydrazine, and hydroxylamine. Such substances obviously combine with the enzyme to exert their protective effects. The combining group of the protective substances is a basic group common to them all, either $-NH_2$ or $=NH$. Combination takes place at a negatively charged group of the enzyme, and presumably this is one of the groups with which urea also is combined.

RECEPTOR-GROUPINGS IN THE ENZYME

Just as there must be a special attachment-grouping in a substrate to enable it to combine with an enzyme, so there must be a special grouping in the enzyme to receive and activate the substrate. The most important way of detecting the chemical nature of such a receptor-grouping in an enzyme is by the use of selective poisons. An example of this group is the thiol radical (–SH). This has been shown to be present in widely different enzymes such as succinic dehydrogenase, urease, papain, and triose-phosphate dehydrogenase. The detection of the thiol group has been accomplished by making use of the poisonous action on the enzyme of reagents known to react with –SH groups. Such a reagent is iodoacetic acid, which brings about irreversible poisoning as it combines with the –SH to form a relatively stable compound. It is possible, however, for certain reagents to oxidize the –SH to –S–S–, eliminating enzyme activity, and when this is reduced to –SH again enzymic activity is restored. Both basic and acid radicals form receptor groups of enzymes. This is shown by the poisonous action of acid and basic dyes, which react with the enzymes, and by the protection of the enzymes by their substrates from inactivation by dyes. It has been shown that invertase combines with acid and basic dyes according to mass action laws and that sucrose will compete with the dyes for the enzyme.

PROSTHETIC GROUPS AND COENZYMES

Spectroscopic examination of catalase, the enzyme which breaks down hydrogen peroxide to oxygen and water, has shown the presence of an organic iron complex (haematin), which has been separated from the protein of the catalase and found to be identical with the organic iron complex contained in haemoglobin. This complex consists of an iron atom associated with four

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

substituted pyrrole rings, and is termed an iron-porphyrin. The enzymic activity of catalase is directly related to its content of haematin, whose combination with cyanide, hydrogen sulphide, etc., results in the poisoning of the enzyme. There appear to be four iron atoms in each molecule of catalase. The mechanism whereby catalase breaks down hydrogen peroxide is associated with the iron-porphyrin complex, which undergoes a cycle of reduction and oxidation. The theory proposed by Keilin and Hartree is that the iron in the haematin of catalase exists in the ferric state, and becomes reduced to the ferrous condition on addition of hydrogen peroxide, oxygen being liberated. The ferrous complex is reoxidized to the ferric state by molecular oxygen, and the cycle recommences. This is illustrated by the following equations:

$$4Fe^{+++} + 2H_2O_2 = 4H^+ + 2O_2 + 4Fe^{++}$$
$$4Fe^{++} + 4H^+ + O_2 = 4Fe^{+++} + 2H_2O$$
$$2H_2O_2 = 2H_2O + O_2$$

Such a view involves the conclusion that catalase would be quite ineffective as a catalyst when in the fully reduced condition. There is still some controversy as to whether this is actually the case. It is important, however, to realize that the special protein in the catalase to which the haematin is united must be playing an important role in the reaction. For haematin attached to a globin, as in methaemoglobin, has an activity which is only one millionth part of that of catalase. The haematin of catalase is often referred to as the prosthetic group of the enzyme. Peroxidase, an enzyme catalysing oxidations by hydrogen peroxide, is another iron-porphyrin complex associated with a special protein, and in this enzyme the iron always remains in the tervalent state. It is clear that iron-porphyrins combined with certain special proteins produce different enzymes, but not all compounds of iron-porphyrins with proteins have catalytic activities. In the protein moiety of the enzyme, special groupings must exist which collaborate with the haematin in conferring catalytic activity on the enzyme complex. The nature of such groupings is as yet unknown.

With other oxidizing enzymes such as polyphenol oxidase and laccase, copper instead of iron plays a dominant role. When the copper of polyphenol oxidase is removed by dialysis, the copper-free protein is without oxidase activity. Addition of copper ions in small concentrations to this protein restores the oxidase activity; the copper ions alone at these concentrations have no activity.

The copper content of these enzymes is small and of the order of 0·2–0·3 per cent. The copper cannot be replaced by other metals such as iron, cobalt, nickel, manganese, or zinc. The activity of the purified enzymes is very high. Thus 1 mg. of polyphenol oxidase will cause a litre of oxygen to be consumed in 1 hour in presence of an excess of a substrate such as catechol. As in the case of the iron-porphyrin enzyme, it is supposed that the copper exerts its catalytic activity by undergoing a cycle of reduction and oxidation.

Recent work has shown the increasing importance of metal protein complexes in enzyme activity. Magnesium seems to be essential for many reactions involving the transfer, or liberation, of phosphate groups. Zinc is an indispensable constituent of the enzyme carbonic anhydrase which controls the release of carbon dioxide from carbonic acid. Cobalt, manganese, and molybdenum are elements known to be important in physiological processes, and doubtless they will be found to be involved in specific enzyme reactions.

Dialysable stable organic substances are now known to be intimately associated with the demonstration of normal cellular activities of certain enzymes. These compounds, which themselves are catalytically inert, are sometimes referred to as co-enzymes, sometimes as prosthetic groups. They are known to be capable of combining with special proteins and may be considered as structural components of the protein complexes. They have acquired a high importance, not only for the parts they play in enzymic reactions, but for the activity which some of their constituents exert in the nutrition of the living cell. Vitamin B_1 (thiamin), vitamin B_2 (riboflavin), and nicotinic acid, all essential dietary constituents, have well-defined functions in enzymic reactions.

The mode of action of a number of these substances is now fairly clear. After combining with a specific protein or enzyme, the coenzyme undergoes a cycle of reduction and oxidation. To take an example. The first discovered coenzyme, termed cozymase, has been found to be a compound of adenine, ribose, phosphoric acid, and nicotinamide. Its constitution is as follows:

Nicotinamide — Ribose — Diphospho-group — Ribose — Adenine

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

and it is often referred to as diphosphopyridine nucleotide. This coenzyme combines with its enzyme, e.g. alcohol dehydrogenase, to form a highly dissociable compound. The substrate (in this case alcohol), after combination and activation by the enzyme, reduces the cozymase, also combined with the dehydrogenase. A transfer of hydrogen takes place, the alcohol being oxidized to acetaldehyde and the cozymase being reduced to a compound in which the double bond in the nicotinamide part of the nucleotide becomes hydrogenated. The two molecules—acetaldehyde and reduced cozymase—are released from the enzyme, and the reduced cozymase is now re-oxidized in its turn to cozymase, either by oxygen through the intermediate action of yet another enzyme (flavoprotein), or by an oxidizing agent such as ferricyanide, in which reaction another enzyme is not involved. Thus the cozymase acts as a catalyst in a chain of reduction and oxidation whereby the hydrogen of alcohol is finally transferred to oxygen or other oxidizing agent. The cozymase must be combined with an enzyme—in this case alcohol dehydrogenase—to perform its function. Cozymase will act as coenzyme, or prosthetic group, to a number of dehydrogenases, each of which consists of a different protein. In general, the function in the cell of a coenzyme, such as cozymase, appears to be that of a middleman capable of receiving hydrogen from various substrates, activated by different enzymes, and passing it on to a variety of other substrates activated by *their* enzymes. It links together a number of enzyme-controlled oxidative reactions. In the living cell the coenzyme may be considered as a regulator of the speed and passage of hydrogen from one set of substances to another, and in this way it helps to control the rates and courses of oxidative processes in the cell.

The enzyme which brings about the oxidation of reduced cozymase is a flavoprotein (a compound containing riboflavin or vitamin B_2). This consists of a special protein which combines with a coenzyme or prosthetic group called flavin-adenine nucleotide. Its constitution is as follows:

Isoalloxazine — Ribose — Diphospho-group — Ribose — Adenine

Reduced cozymase when combined with this enzyme reduces the flavoprotein, cozymase being re-formed, while the flavin nucleotide is reduced at the isoalloxazine ring. Reduced flavoprotein is now oxidized in its turn through another enzyme system (cytochrome and cytochrome oxidase), until eventually oxygen itself is reduced. The similarity in structure between flavin-nucleotide and cozymase is very striking, the only difference lying in the nature of the reducible groups. The flavin-nucleotides enter, however, into much firmer unions with their specific proteins, the chemical nature of these unions being as yet unknown. It is noteworthy that the pyridine- and flavin-nucleotides are derivatives of adenyl triphosphate, which is itself a coenzyme of glycolytic systems. It can be no coincidence that compounds containing adenylic acid, which form so important a part of the chemical architecture of a cell, play a significant role in cell oxidative processes. Another coenzyme is cocarboxylase, also termed the pyrophosphate ester of thiamin or aneurin or vitamin B_1. Its constitution is as follows:

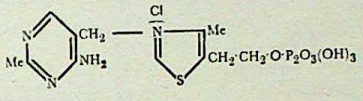


TABLE 3

Enzyme	*Prosthetic Group or Coenzyme*	*Reactions catalysed*
Catalase	Iron-porphyrin	$2H_2O_2 \rightarrow 2H_2O + O_2$
Peroxidase	Iron-porphyrin	Oxidations by H_2O_2
Polyphenol oxidase	Copper	Oxidation of *o*-diphenols, etc.
Laccase	Copper	Oxidation of *p*-phenylenediamine and diphenols
Ascorbic oxidase	Copper	Oxidation of ascorbic acid (vitamin C)
Carbonic anhydrase	Zinc	$H_2CO_3 \rightarrow CO_2 + H_2O$
Phosphatases, Phosphorylases	Magnesium	Reactions involving transfer, or liberation, of phosphate groups
Alcohol, lactate, malate, glucose, glycerophosphate dehydrogenases	Cozymase (Diphosphopyridine-nucleotide)	Oxidation of corresponding substrates to aldehydes and ketonic acids
Hexosemonophosphate dehydrogenase	Triphosphopyridine nucleotide	Oxidation to phosphohexonate
Flavoprotein	Flavinadenine-nucleotide	Oxidation of reduced forms of diphospho- and triphospho-pyridine nucleotides
Amino-acid oxidase	Flavinadenine-nucleotide	Oxidation of *d*-α-amino acids to ketonic acids
Xanthine and aldehyde oxidases	Flavinadenine-nucleotide	Oxidation of purines and aldehydes
Carboxylase	Diphosphothiamin (Cocarboxylase)	$R{\cdot}CO{\cdot}COOH \rightarrow R{\cdot}CHO + CO_2$
Pyruvic acid oxidase	Diphosphothiamin	Oxidation of pyruvic acid in brain, bacteria, etc.
Acetic acid oxidase	Diphosphothiamin	Bacterial oxidation of acetic acid

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

This molecule forms a dissociable complex with a special protein, and is then capable of breaking down α-keto-acids into the corresponding aldehydes and carbon dioxide. The special protein and the cocarboxylase, though individually inert, together form an active enzyme system. This coenzyme is now known to be essential for the oxidation of pyruvic acid in animal tissues, and of acetic acid by bacteria. The mechanism of its action is not yet elucidated. A list of enzymes and their coenzymes is shown in Table 3.

CELL-METABOLISM

A few examples taken from diverse fields of cell-metabolism will suffice to show how systems of enzymes are involved in the familiar metabolic processes of the cell.

Alcoholic fermentation, the study of which has so greatly enlarged our knowledge of the mode of action of enzymes, is made up of a large number of enzyme-catalysed reactions which may be summarized as follows:

$$\text{glucose} \xrightarrow{\text{phosphorylase}} \text{hexosemonophosphate}$$

$$\xrightarrow{\text{phosphorylase}} \text{hexosediphosphate}$$

$$\text{hexosediphosphate} \xrightarrow{\text{zymohexase}} \text{triosephosphate}$$

$$\text{triosephosphate} \xrightarrow{\text{dehydrogenase}} \text{3 : phosphoglyceric acid}$$

$$\text{3 : phosphoglyceric acid} \longrightarrow \text{2 : phosphoglyceric acid}$$

$$\text{2 : phosphoglyceric acid} \rightarrow \text{phosphopyruvic acid}$$

$$\text{phosphopyruvic acid} \xrightarrow{\text{phosphorylase}} \text{pyruvic acid}$$

$$\text{pyruvic acid} \xrightarrow{\text{carboxylase}} \text{acetaldehyde}$$

$$\text{acetaldehyde} \xrightarrow[\text{alcoholdehydrogenase}]{} \text{alcohol.}$$

In the various phosphorylations mentioned above adenyltriphosphate plays a vital catalytic role, whilst in the other processes coenzymes involving nicotinic acid (as cozymase) and vitamin B_1 (as cocarboxylase) are concerned.

The synthesis of urea from ammonia and carbon dioxide in the intact liver-cell appears to depend on the enzyme-catalysed reactions set out below*.

Here ornithine acts as a catalyst in the synthesis of urea, but its reactions are controlled by appropriate enzymes.

In tea fermentation, to take a widely different system, familiar cell-respiratory catalysts are concerned. The main reactions involved have been described as follows:

$$\text{tea-tannin} + O_2 \xrightarrow{\text{cytochrome oxidase}} o\text{-quinones}$$

$$\text{glucose} + o\text{-quinones} \xrightarrow[\text{dehydrogenase}]{\text{glucose}} CO_2 + \text{tea-tannins}$$

$$o\text{-quinones} \xrightarrow[\text{processes}]{\text{condensation}} \text{polymers (brown pigments characteristic of fermented tea).}$$

Cyclic processes, involving special proteins or enzymes, together with a variety of substances working at low concentrations and specifically associated with these proteins, are common features of metabolic events in the living cell. It is to be expected that our knowledge of these processes will grow as the kinetics of cell-metabolism are further investigated.

*(i)

$$NH_3 + CO_2 + \underset{\text{ornithine}}{NH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH} \rightarrow O=C(NH_2)\cdot HN\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH$$

citrulline

(ii)

$$O=C(NH_2)\cdot HN\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH + NH_3 \rightarrow HN=C(NH_2)\cdot HN\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH$$

arginine

(iii)

$$HN=C(NH_2)\cdot HN\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH + H_2O \xrightarrow{\text{arginase}} CO(NH_2)_2 + \underset{\text{ornithine}}{NH_2\cdot CH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)\cdot COOH}$$

urea

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Science in the service of the fine arts

Digitized by Arya Samaj Foundation Chennai and eGangotri

IAN RAWLINS

Physics and chemistry now play a considerable part in our understanding of works of art, as well as in problems of their conservation and the provision of appropriate environment. The philosophical psychology of art is being intensively studied, especially in relation to *Gestalt* theory: the aesthetic question is seen against the background of the concept of the beautiful in mathematics. In much of this work, Great Britain has led the way.

The Golden Age of Greece produced scientists, mathematicians, and philosophers. Fortunately, much of their work is with us today. Far less known, however, are the pictorial artists of the same period. But to judge from the evidence of their achievements in the forms of descriptions or copies—nearly everything original having been lost or destroyed—the standard must indeed have been formidable. The social and educational aspects were not overlooked, for we know that public exhibitions of paintings took place, and that private collectors were urged to make over their property to the State for the general good. History is indeed closely repeating itself in our own day.

But those far-off times showed a tendency which, sadly enough, was later to suffer almost complete eclipse for several centuries, only to reappear in Italy and the Low Countries of Europe. It was a kind of intimacy between the arts and sciences, an intellectual federation in which each partner was willing to contribute what it could to the common culture. The stress of antithesis between the two outlooks, so destructive and withal so sterile, had not yet set in. The loss of this unity, when it came about, was a disaster the magnitude of which we are only now beginning to appraise. Not content with that, history shows that much the same happened again when the technical skill of the Baroque artists suggested that associated research, as such, was temporarily at an end. Their joy was to exploit the newly won victories of anatomy and structural perspective. It was a glorious if improvident epoch: glorious in the genius of Rubens, for instance, but improvident in exhausting all too rapidly the comparatively slender stock of scientific thought.

The present situation displays features at once encouraging and perplexing. The role of science has shifted. Its part is not so much with the artist as with the beholder, and with those whose task it is to conserve great works of art and to exhibit them worthily. This article discusses, therefore, some recent developments in these fields, with particular reference to what has so far been accomplished in Great Britain. But the aim there, and in the United States no less, goes much deeper than mere doctoring and hygiene, important as they are. An attempt is being made to apply the principles of physics and chemistry to art, and to know thereby more of how the great masters worked, and how they produced the supreme examples of their skill, imagination, and devotion. In addition, a change of emphasis can be discerned in our reactions to, say, a great picture. We wish to know not only what it represents but what it means. An artist's technique is no longer a case of 'that's that,' but a subject to be probed for its significance. This is a vital distinction and embodies a new principle. We find ourselves confronted with some of the most profound problems of philosophical psychology, in particular with the theory of *Gestalt*. This was originally a Teutonic doctrine, and its aim, in brief, was to merge into one the quantitative and qualitative aspects of experience: in fact, an outlook pregnant with possibilities for the interplay of the arts and sciences. To Great Britain perhaps should go the credit for grasping the potential value of the theory in these directions. Even in war-time, research of this kind is going on, taking baby steps as yet, fitful and insecure, along completely new and untrodden paths of thought.

In Britain, laboratories fully equipped with physical and chemical appliances have been in existence for some years at the British Museum, the National Gallery, and the Courtauld Institute. The first of these has recently celebrated its coming of age, whereas the other two have each been at work for about a decade. In the U.S.A., a comprehensive Department of Conservation and

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Research is part of the Fogg Art Museum in the University of Harvard. Scientific methods are also being developed in connection with the museums and galleries at New York, Baltimore (Walters Foundation), and Boston. The purpose of all these is much the same, and a welcome degree of co-operation has been established between the national institutions in Great Britain and their counterparts across the Atlantic. An example is the regular exchange of X-ray photographs (which functioned before the war) between the National Gallery and the extensive collection accumulated at the Fogg. This sharing of knowledge has proved mutually beneficial; overlapping is avoided, and a common research programme was in process of formation in 1939, so that the special apparatus at either institution could be used to the best advantage without duplication. Great possibilities are thus open when happier times return.

In the sequel, consideration will mainly be given to the scientific laboratory of the National Gallery, London, but much of what goes on there is equally applicable—*mutatis mutandis*—to other places in which the chief interest may be in works of art other than pictures.

A typical example—from pre-war days of course—will perhaps show what can be done better than abstract descriptions. A picture is thought a proper subject for cleaning: that is, its discoloured varnish is to be removed, and very probably the repaint as well, which is assumed to cover part of the original design. The question therefore arises as to how much of the artist's original work is actually present beneath the layer or layers of repaint. X-ray photographs will be taken. How much they will reveal depends upon a number of factors which the scientist unfortunately cannot control, but which he may be able nevertheless to anticipate. But in favourable cases he will be able to produce a first-class image of what lies hidden, and thus largely to determine whether or not the proposal to clean goes ahead. In this connection, it is well to be perfectly clear that the decision is—in the last analysis—not a scientific one at all, but is based essentially upon aesthetic considerations. Will the picture, in fact, be more lovely after cleaning than before or not? Thus, X-ray tests show, when properly interpreted, whether cleaning would be justified technically; they make no judgment whatever upon the problem of the beautiful. Lack of appreciation of this elemental distinction has often led to much disappointment and confusion. The moral is in reality applicable to the fine arts in general, in that no scientific methods as such can ever pronounce upon stylistic and kindred questions. To ask them to do so is radically to mistake their function. But rightly understood and carefully used, their value is immense.

In addition to radiography, the laboratory will apply ultra-violet and infra-red analysis; the former is often used visually, the latter is necessarily photographic. Varnish shows strong fluorescence in ultra-violet light; it will thus be clear to the restorer when this layer has been effectively removed. Cases have occurred in which repaint has been present on top of the varnish, and this of course becomes immediately apparent. With the varnish layer absent, ultra-violet rays may give valuable hints about the age and chemical composition of paint. Taken in conjunction with the history of the work under examination, valuable supplementary information may reasonably be expected. In other branches of the arts—sculpture and ceramics especially—ultra-violet testing is often effective in revealing hidden mends, refillings, and even portions added at later dates.

Infra-red photography may be applied at the outset, or subsequently, or both, in a programme of restoration. Owing to the marked penetration of these rays through discoloured varnish, a criterion of the condition of the design beneath can be obtained. Very great care is needed in reading such photographs, for the reflective powers of pigments for these long waves are quite different from the corresponding values in visible light. The influence of the binding medium (oil, tempera, wax, and so forth) has also to be taken into account. With the varnish in good condition, and reasonably thin, it may be possible to peer beneath the surface of the paint and to bring out the under-modelling. This may not be of significance for the limited purposes of restoration, but it is of paramount importance for a study of the history and development of technique. There is no doubt that the infra-red possesses advantages over the other radiations in certain respects. Compared with X-rays, for example, the absence of superposition of the images of several layers (wood or canvas, priming, paint) upon each other is a welcome simplification. Further research may well be devoted towards methods designed to register the presence of paint layers at greater depths than is now possible. Nevertheless a word of caution may not be amiss. Oddly enough, what has hindered infra-red progress in the fine

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 1 (*b*) – *A Lady in a Plumed Hat.* (*Flemish School, sixteenth century.*) *This X-ray photograph, compared with figure* 1 (*a*), *shows a favourite technique of the period, whereby the artist started with a black background, building up the features by successive additions of lead white. Possibly a little lead white was even mixed with the under layers.* (*Detail of National Gallery, London, No.* 4,033. *Courtesy of the Trustees.*)

FIGURE 1 (*a*) – *A Lady in a Plumed Hat.* (*Flemish School, sixteenth century.*) *Photograph in ordinary light.* (*Detail of National Gallery, London, No.* 4,033. *Courtesy of the Trustees.*)

...Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 2 (*b*) – *St Vincent Ferrer by Cossa. Compared with figure 2 (a) this infrared photograph shows the characteristic under-modelling (shading) on the saint's left temple, cheek, and neck, due to deep penetration by the rays. Except for the saint's left*

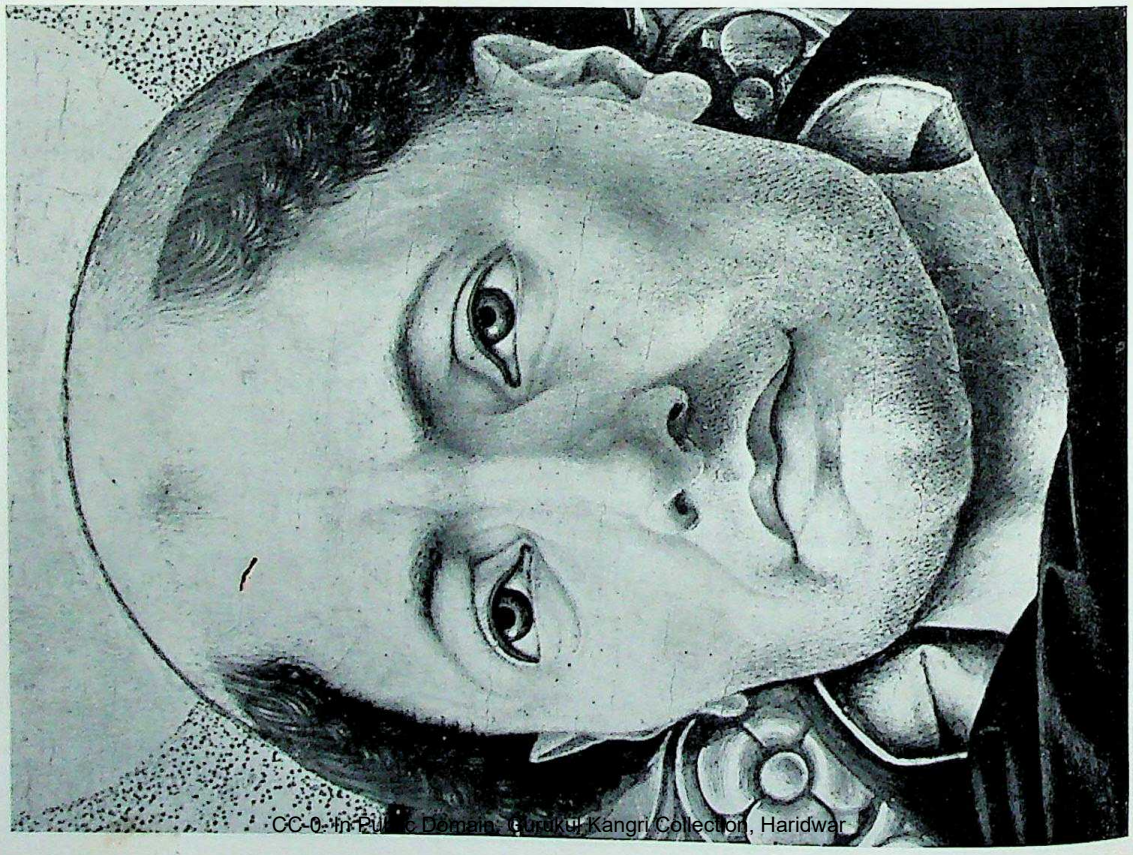


FIGURE 2 (*a*) – *St Vincent Ferrer by Cossa. Photograph in ordinary light.* (Detail of National Gallery, London, No. 597. Courtesy of the Trustees)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

arts more than any other single factor is the view that it is easy and straightforward. To get results of a sort is indeed not too difficult, but to bring these long waves under sufficient control to enable really trustworthy and reproducible data to accrue is altogether another matter. This brief outline will suggest what a sizable dossier is likely to accumulate regarding a picture about to be cleaned if the operation is conducted scientifically. It is a very far cry from the practice of the past. There are two more tasks at least to be performed before our information may be considered complete, and these will now be described. It is remarkable how knowledge of objects of art has advanced by these intensive methods.

The introduction of the microscope into the gallery laboratory is not new. Binocular instruments of various kinds have been used by restorers for some time. Occasionally a kind of dissecting stand is helpful. What, however, is novel is the part played by polarized light incident upon the surface of a painting. The reason for its use is peculiar. It is to reduce—in fact, almost to eliminate—scattered light (flare), and so to enable the observer to get a sharp image by reflection. Powerful illumination is essential, since much loss of intensity results, in spite of the employment of special lenses taking light from peripheral rays.

With this arrangement, minute cracks in the paint-films stand out boldly, and it is possible with practice to see whether repaint has 'slopped' over them or filled them up. Much the same applies to accumulated dirt in small fissures. The magnifications involved are usually very moderate, seldom exceeding 70 diameters.

Finally comes the tintometer for the study of colour changes. It is obviously desirable to be able to set a numerical value to the tonal intensity of some exceptionally interesting area of a painting before and after cleaning. This is achieved by an apparatus (the tintometer) employing the comparison of two visual fields, one reflected from the painting and the other from a block of standard white magnesium carbonate. A match is obtained by the interposition of coloured glass screens, specially made to retain their absorptive powers unimpaired over long periods. Results are readily tabulated for future reference.

It will be noticed that these five methods (X-rays, ultra-violet, infra-red, microscopy, tintometry) are all in the nature of 'non-destructive testing.' The painting itself is not touched in any way. In this respect, they are ideal. If, however, the analysis of a pigment or medium is considered essential, it may be necessary to remove a minute amount (less than the size of a pin's head) from the edge or from under the rabbet of the frame, for analysis by micro-chemical or spectro-photographic means, preferably the latter. Occasionally, but not often, some crucial point can be settled in no other way.

Corresponding progress has been made with the elucidation of the characteristics and condition of other valuable objects such as ceramics and metals, including ancient bronzes. The Research Laboratory of the British Museum, London, was a pioneer in this field, and today stands unrivalled both for the precision and refinement of its investigations and for the exceptionally wide range of its activities. In Great Britain the Department of Scientific and Industrial Research (D.S.I.R.) has proved a godsend in undertaking special inquiries of interest to curators. Examples are the identification of wood species (important for the history of panel paintings) and the control of moulds and mildew. Co-operation between this Department and art laboratories has proved most beneficial.

Another set of problems altogether is encountered when the question of the best physical environment for valuable objects is considered. Clearly, this matter concerns not only officials, but the public as well. Picture galleries and museums must normally be maintained at temperatures and relative humidities reasonable for the comfort of visitors. Generally, relative humidity is more important for exhibits than temperature, and luckily the former may be fixed within surprisingly wide limits without causing bodily inconvenience. Thus, physicists and engineers will probably agree that a relative humidity of around 55 per cent. at 65° F is appropriate, and these figures are comfortable, in the British Isles at any rate. The difficulty, naturally, is to keep these conditions from wide fluctuations, when the number of persons present in the building may vary greatly. It is probable that no institution has solved the problem completely. For the moment, all that can be said is that extensive data are being accumulated as the result of wartime storage of valuables of all kinds under scientific control.

At the beginning of this article, the changes which have occurred since early times in the relationship between the arts and sciences were briefly reviewed. In the light of modern developments, now in outline at least before the reader, it is tempting to glance into the future. Given a

FIGURE 2 (a) – St Vincent Ferrer by Cossa. Photograph in ordinary light. (Detail of National Gallery, London, No. 597. Courtesy of the Trustees)

FIGURE 2 (b) – St Vincent Ferrer by Cossa. Compared with figure 2 (a) this infrared photograph shows the characteristic under-modelling (shading) on the saint's left temple, cheek, and neck, due to deep penetration by the rays through the top paint layer.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

return to a semblance of normality, scientists can be trusted to persevere in their efforts for the preservation and due display of works of art. But their claim may, in time, be found to be very much greater. It may well be that the fascinating but troublous subject of aesthetics will yield appreciably to a scientific approach, more especially in the direction of *Gestalt* principles.

Efforts of this kind are bound to be slow and tentative; they offer perhaps wider vistas and greater triumphs than almost any other intellectual quest, if fearlessly pursued. One thing essential to realize is that the arts are not the only expression of the beautiful: in mathematics especially there are branches which to describe as 'elegant' would be an understatement. The elusive property of what exactly constitutes mathematical beauty is in fact no bar to its certain recognition by those qualified to judge, in very much the same way as in the fine arts. Somewhere hereabouts we must rediscover in this twentieth century the link that was so unhappily severed over two thousand years ago. An eminent Cambridge scholar recently wrote:

> He [the mathematical research worker] should take simplicity into consideration in a subordinate way to beauty. . . . It often happens that the requirements of simplicity and of beauty are the same, but where they clash the latter must take precedence.

A stronger urge for science in the service of the fine arts would indeed be hard to find.

Correspondence

(*Continued from page* 84)

LAVOISIER AND CONTEMPORARY BRITISH CHEMISTRY (continued)

propounded in 1777; and at the same time he applied Black's discovery of latent heat to formulate a theory of gases. But his ideas found no acceptance. It may be that he was waiting far less for the acclamations of his fellow-Academicians in Paris than for an approving voice from Edinburgh, the voice of Black, then the most eminent of living chemists, whose ideas had so greatly inspired him and of whom he spoke as 'mon maître' and 'le premier de mes juges.' We do not know the exact date of Black's acceptance of Lavoisier's theory, but we know that it was before 1784. (The first French chemist to be converted was Berthollet in 1785.)

In 1784 Cavendish discovered that the explosion of 'inflammable air' and Priestley's 'dephlogisticated air' yielded water, and concluded that the water was produced by condensation from both 'airs,' 'inflammable air' being 'water united to phlogiston' and 'dephlogisticated air' being 'water deprived of its phlogiston.' But Lavoisier saw at once that Cavendish's discovery vitally confirmed his own theory, and he gave the explanation that water was a compound of these gases.

The sequence of experimental discovery was now complete—Black, Priestley, Cavendish. Soon afterwards, Lavoisier applied Boyle's definition of the chemical element and drew up the first list of elements. Priestley's 'dephlogisticated air' became the element oxygen; Black's 'fixed air' became a compound of oxygen and the element carbon; and water a compound of oxygen and the element hydrogen.

Freed from his administrative labours by political changes, Lavoisier hoped to visit England and to meet Black in Edinburgh. Unhappily, his life was already threatened. However, we might point out on this two hundredth anniversary of his birth that there seems some reason to suppose that, shortly before his death, the Council of the Royal Society, of which he had been elected a Foreign Member in 1788, was considering the award to him of the Society's highest honour, the Copley Medal. Grimaux stated that the award was actually made in December 1792, but this is not so. The Copley Medal was awarded to Rumford in 1792 and to Volta in 1794. Significantly, there was no award for 1793, although the Council discussed the matter without recording anything of their intentions or considerations. Grimaux's '1792' may be a slip; his dates are often wrong. It was a time, however, when the award of a medal from London would be likely to bring not distinction, but mortal peril, to a Frenchman, especially one so closely associated with the old régime, and the Council would be well aware of this. Already in September of 1793 Lavoisier had been subjected to a domiciliary visit for his papers to be searched. In November 1793 he was arrested; and he remained in prison until guillotined on 8th May, 1794. During the domiciliary visit of September 1793, a packet of letters from correspondents in this country was taken from him; and it may be that one or other of these contained some hint of the intentions of the Council of the Royal Society. The letters have survived, but an examination of them has been prevented by the events of the war. Other relevant documents are also inaccessible at present, but it is hoped to obtain further information on this matter after the war.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

The chemistry of gemstones

Digitized by Arya Samaj Foundation Chennai and eGangotri

W. T. GORDON

Shakespeare's line, 'These be rubies, fairy favours,' well expresses the almost magical fascination which the enduring beauty of precious stones has always exerted upon the mind of man. We now know much of their structure and composition, but, as Professor Gordon points out in the following article, chemistry has not yet met with full success in making artificial gemstones indistinguishable from the corresponding natural ones.

Gems are prized because of their beauty, but this beauty must be lasting; consequently resistance to conditions that would impair their attractive characters must be one of the most important properties of gems. The innate acquisitiveness of man compels rarity to be considered as another very desirable feature, and, further, any material from Nature's storehouse is valued far above the products of chemical science in the laboratory. Man persists in regarding himself as something apart from Nature, and as long as his manufactured gems can be differentiated from the corresponding natural types, so long will he relegate some of the triumphs of chemical skill to an inferior category. In regard to the rarity factor, an analogous statement may be made. A mineral may perhaps be too common to be considered anything but a semi-precious gem, even though it is very attractive; or, on the other hand, it may be so rare that a vogue cannot be established for it as a gemstone, and only the well-informed collector is aware of its existence and its beauty.

Beauty in a gem is based on emotions aroused by the effects of light, whether by reflection, absorption, refraction, dispersion, or interference of rays, and these are physical, not chemical, characters. Indeed, one may almost as appropriately talk of the chemistry of the rainbow as the chemistry of gemstones. Yet, just as there is a chemistry of air and water, the media that produce the rainbow, so there is a sense in which the chemistry of gems has a real existence.

Since the fundamental phenomena associated with gems are physical, it is not surprising to find that they occur in many different chemical groups. The range is from elements, through simple oxides, to exceedingly complex silicates, phosphates, and other salts. And the most fascinating chemical considerations centre around attempts to make synthetic or reassembled products that are identical with natural minerals as regards colour and optical behaviour. Failure has attended most of these attempts, but, in a few cases, remarkable success has been achieved.

Analysis of gemstones is usually simple, but *reassembly*, involving not merely correct chemical constitution but also correct physical arrangement of the atoms, has not proved so easy. The early attempts were abortive because the experimenters could not secure correct physical 'build' of the constituents within the conditions of their methods. Naturally, a process that will form a clear limpid substance out of the material elements of a gem may not necessarily secure the proper physical lattice structure, and a structureless glass, rather than a crystal, might be expected.

Diamond and corundum were the two chief gems whose artificial production was most desired. The former has eluded the efforts of chemists up to the present in any large sizes, though J. B. Hanney's claim to have made small diamonds in 1880 has been substantiated again in recent weeks. Mr F. A. Bannister and Dr K. Lonsdale have proved that some of the minute crystals he made in that year have the diamond pattern structure[1]. But large-scale production is hardly likely along the lines of his method.

Ruby and sapphire were reassembled most wonderfully in 1904 by means of the Verneuil inverted blowpipe (figure 1). Curiously enough, earlier workers recorded that when they fused ruby or sapphire an opaque globule was formed. The significance of this was not realized, but essentially the reason is that corundum—the substance of ruby and sapphire—always crystallizes on cooling from fusion, and usually as a confused jumble of minute crystals; consequently opacity of the mass supervenes. Until conditions that permitted of the continuous growth of one single crystal were discovered no success was

[1] *Bull. Min. Soc.*, meeting 28th January, 1943.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

attained. Verneuil's process depends on the production of finely powdered aluminium oxide by calcining ammonium alum at 1,000° C and dropping the powder through the flame of an oxy-hydrogen, oxy-acetylene, or oxy-coal-gas inverted blowpipe. The powder melts in the hottest part of the flame, and the small droplets fall on to the end of a fireclay rod placed just below that level. At first a forest of small crystals is produced, each crystal more or less parallel to its neighbours (figure 3), but soon one begins to increase in size at the expense of the others. The powder 'feed' is then increased and the heat of the blowpipe is stepped up to 2,100° C. An inverted pear-shaped mass or 'boule' is gradually formed. It is a single crystal of corundum, round in transverse section, though hexagonal shapes, like the natural crystal, are sometimes produced[1].

The artificial crystal shows an interesting difference from a natural crystal because the whole 'boule,' aside from the small initial 'stalk,' splits down the centre. Until the parting is effected the whole is in strain, but, after fracturing, the two halves are free from strain. Gems are often cut from the two halves in such a way that the front faces are parallel to the plane of parting; but the colour of the ruby type in particular is different in this direction from that in a plane perpendicular to the parting, and it happens that the colour most in demand is the latter. In natural crystals there is no similar plane of parting, and so the most desirable colour may be secured without sacrificing material. The experienced eye can differentiate the 'synthetic' from the natural gem by this test, though there are easier and more certain tests available.

There is no outward sign of this very important plane of parting. But, on holding the small end of the boule between the jaws of a pair of nippers and attempting to break the end off by a sudden twitch, it is found that, in one direction, the whole boule splits lengthwise into two nearly equal parts. It is possible that this surface is a twin plane—a feature that occurs in other crystals, e.g. augite or hornblende among rock-forming silicates.

Another interesting point is that the axis of the boule is not in general the axis of the crystal. The angle between the two directions may range up to 40°, and for jewels for bearings the crystallographic direction is important. The true axis is accurately determined by examination of the small basal portion, and is marked on each half before the cutting out of the jewels is begun. Large boules are best because the larger the boule the fewer are the measurements of axial orientation required. By keeping all materials pure, boules up to 750 carats (= 150 gm.) have been manufactured (cf. figure 3).

For jewellery purposes the corundum must be coloured, and this is done by adding certain metallic oxides, again in a finely divided state. Ruby is made by adding up to 2·5 per cent. of chromic oxide, sapphire by the addition of 1·5 per cent. iron oxide and 0·5 per cent. titanium oxide (later altered to 0·12 per cent. of titanium oxide alone), while up to 3 per cent. vanadium oxide produces the so-called synthetic alexandrite. Like the true alexandrite, the material is greenish in daylight but raspberry-red in artificial light. The absolute riot of colour that may occur in natural corundum is illustrated in figure 9, and all these colours could be imitated by adding suitable oxides to the original alumina powder (figure 4).

In the early process of manufacture the colour did not always spread evenly through the molten mass. Curved bands of colour, quite distinct from the straight bands that often occur in the natural crystal, appeared; but a uniform colour dispersion was effected by adding magnesium oxide. The resulting 'boule' was square in section, and the taper from the initial stalk had four flat faces on the position of the four corners of the cube (figure 2). The chemical composition approximates to $MgO,3Al_2O_3$. The natural mineral spinel has a formula MgO, Al_2O_3, and crystallizes in the cubic system, so the artificial product may be called a synthetic spinel. All kinds of coloured specimens are made—but made in imitation of other gems. The colour in the natural spinels has a smoky appearance, so that the synthetic material appears in contrast to be too clear and clean (figure 7). Red spinel has chromic oxide and blue spinel ferrous oxide as colouring material.

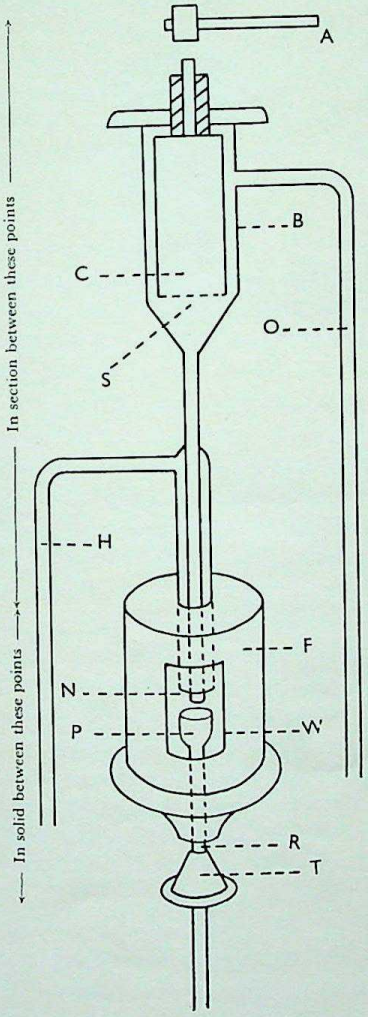
Corundum and spinel are relatively simple in composition, but, in 1935, the successful synthesis of beryl, $3BeO, Al_2O_3, 6SiO_2$, was announced. The material was green in colour and was named igmerald. The process of manufacture is a secret. The colour is frequently in bands, but these bands are straight. Chemically this is an even greater triumph, although detection is comparatively easy. The specimens so far produced are small, about 1 carat (= 0·2 gm.).

[1]Sandmeier, E. G., *J. Inst. Elec. Eng.*, 1933, **72**, 505–514, Pls. 1–6.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

No other important gem type has been synthesized, but there is nevertheless an interest in their colouring material. Glasses made to imitate gems may have certain materials added to produce the desired colour, but such materials may not be identical with those in the natural stone. Perhaps tourmaline shows the difficulty more than most. The analysis of the mineral is not very definite, but certain colours are associated with different compositions. Pale pink and pale green examples have lithium in their composition, and occur with lithia mica; brown to yellow-brown samples have magnesium; and green to black contain iron (figure 8). The luxuriance of colour in gems is also well shown in zircon (zirconium silicate) (figure 6), while figure 5 illustrates the more striking colour variations in topaz and garnet.



Another aspect that may be brought within the purview of the chemistry of gems is the occurrence of 'inclusions,' i.e. one mineral in another, in such a regular fashion that beauty is imparted to the whole. Needles of rutile (titanium dioxide) or asbestos are often regularly positioned under the crystallization forces, and light is therefore reflected from every fibre in the same general direction. There may be only one such direction, or two or three intersecting directions, and luminous beams may appear in the stones. Cat's-eye effects, or luminous crosses or stars, may result. In some cases the amount of foreign substance is too small to be detected by chemical analysis.

Brilliant colour effects may be produced by slight variations in the water present in minerals. If adjacent lamellae vary slightly in water content, light may suffer interference when passing over the laminae. Opal offers the best illustration of this phenomenon. Minute cracks may induce similar results.

Lastly, bright colours due to dispersion of light may appear in perfectly colourless or pale-coloured materials. In diamond (carbon), zircon (zirconium silicate), and sphene (calcium titanate and silicate) very brilliant colours of this type are seen, but they are rather outside the scope of the chemistry of gemstones.

FIGURE 1 – *Verneuil inverted blowpipe.*

A = Tapping device to strike top of spring-suspended alumina container C.

B = Outside of oxygen tube into which container C fits.

S = Sieve base of container.

H = Hydrogen tube.

O = Oxygen tube.

N = Nozzle of blowpipe inside fireclay furnace F seen through window W.

P = Pear-shaped boule forming on fireclay rod R.

T = Table that can be raised and lowered and which accommodates the fireclay rod.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

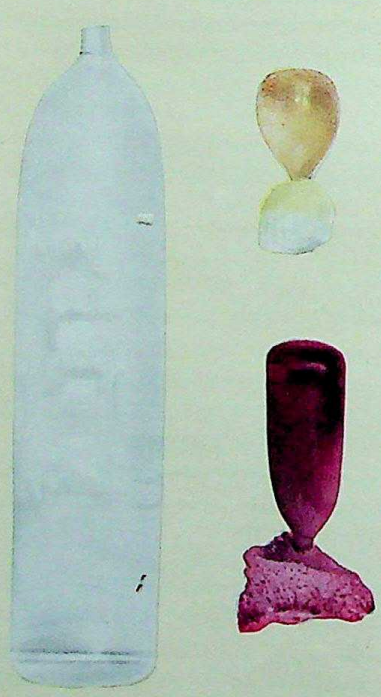


FIGURE 2 (*above*) – *Boules of synthetic corundum and synthetic spinel.*

The upper row are cut corundum gems from boules similar to those in the second row. The third row are boules of synthetic spinel made by the same process as the synthetic corundum. They are square in section, however, as distinct from the rounded hexagonal form of the synthetic corundum.

FIGURE 3 (*left*) – *Synthetic corundum.*

The large 'boule' is in an inverted position. It weighs over 100 gm., or 500 carats. This material is used mainly for pivots in machinery, e.g. meter and watch jewels. The smaller 'boules' show how the crystals develop from one of the 'forest' of small crystals that coat the apex of the fireclay rod in the Verneuil furnace. The ruby 'boule' has several small unsuccessful competitors round its base. These illustrate the several directions in which their axes are orientated.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 4 – *Synthetic corundum and natural blue topaz.*

The top and bottom stones are natural topaz of pale blue colour. The third, down, is padmaradschah.

FIGURE 5 – *Topaz and garnet.*

The seven large stones in the two top rows, and the three bottom specimens, are topaz. All the others are garnet. The colour variation in these gems is great, though not so great as in tourmaline and zircon.

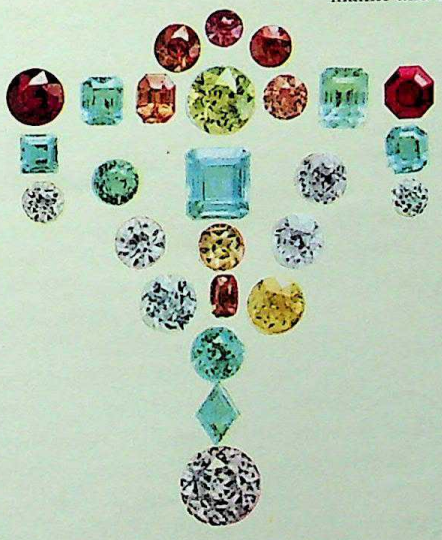


FIGURE 6 – *Zircon.*

A series to illustrate the great variety of colour in specimens of natural zircon. Heat-treatment may change the colour, and the blue examples shown here are almost certainly so treated.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

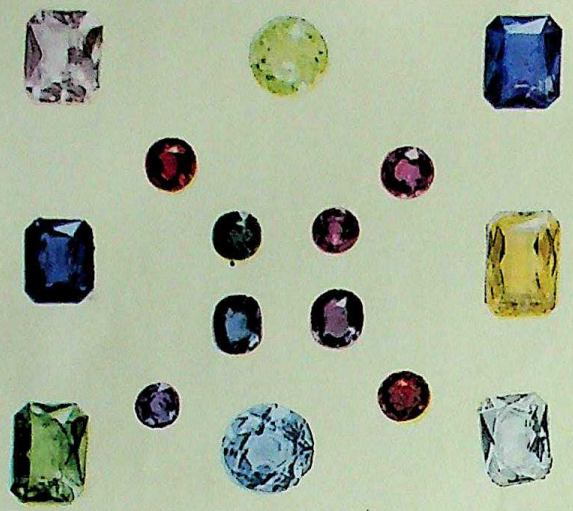


FIGURE 7 – *Natural and synthetic spinel.*

The eight small stones in the centre are natural. The eight large specimens forming the outer frame are synthetic.

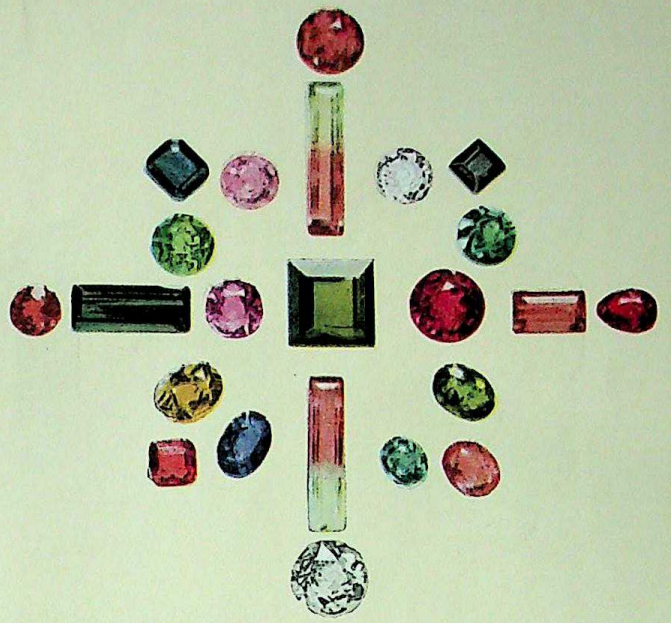


FIGURE 8 – *Tourmaline gems.*

The variety of colour is very great. Deep green specimens are sold as Brazilian emerald, deep blue as indicolite.

FIGURE 9 – *Natural corundum gems.*

The top central purple stone is called oriental amethyst. To the right of it is a cornflower-blue sapphire, to the left is a royal blue sapphire. Below the central white sapphire is a pigeon-blood ruby, and beneath that is a more ordinary ruby. Collectively all unusually coloured corundum gems are called fancy sapphires, but those coloured like emerald, topaz, or amethyst have been designated oriental emerald, oriental topaz or king topaz, and oriental amethyst, respectively.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The earth's gravitational field

Digitized by Arya Samaj Foundation Chennai and eGangotri

E. C. BULLARD

It has long been known that the acceleration due to gravity varies from place to place, though 'obstinately constant' at a given locality. A survey of the earth's gravitational field, including observations made under difficult conditions at sea, has provided much interesting information on geological problems such as mountain-building. Dr Bullard describes some of the methods recently employed and discusses the implications of the data acquired.

The birth of the modern science of physics is marked by the experiments of Galileo on the motion of falling bodies. He found that, if attention is restricted to bodies dense enough not to be affected appreciably by the resistance of the air, the motion is one with a constant acceleration. That is, the velocity of fall increases directly in proportion to the time that has elapsed since the body was at rest. This acceleration is called 'g' and is conveniently measured in centimetres per second per second. Its numerical value in London is about 981, that is to say the velocity of a falling body increases by 981 cm./sec. during every second that it falls. If it starts from rest it will have a velocity of 981 cm./sec. at the end of the first second, 1,962 cm./sec. at the end of the second second, 2,943 cm./sec. at the end of the third second, and so on. If a body is dropped in air its motion is to some extent influenced by the buoyancy and resistance of the air, and for light bodies, such as feathers, the air-resistance is the main factor controlling the motion. In a vacuum all bodies fall with the same acceleration and it is this acceleration in a vacuum that is always implied by g.

The constancy of g at a given place is one of the simplest and most fundamental laws of Nature. It has now become such a commonplace that it is rarely considered as remarkable; it would, however, be difficult to name another property that is totally independent of the material, size, mass, shape, state of aggregation, and temperature of a body. The demonstration of this constancy was started by Galileo and continued in a more sophisticated way by Newton, who established it to 1 part in 1,000 with gold, silver, lead, glass, sand, common salt, wood, water, and wheat. Since then the accuracy has been pushed to 1 part in 160,000,000 by the experiments of Bessel, Eötvos, and others.

The timing of freely falling bodies is not a convenient method of measuring g, and was early replaced by the determination of the period of a pendulum. With a given pendulum the time taken for one oscillation is inversely proportional to the square root of g, and a pendulum can therefore be used to determine variations in g from place to place or from time to time. The period also depends on the form of the pendulum, and the determination of the absolute value, as distinct from the variations from place to place, is an elaborate undertaking. The best method is due to Captain Kater, who used it in 1817 to determine g at the house of his friend Mr Brown, near the site of the present Broadcasting House, London.

In 1672, Richer, a French astronomer, found that his clock, which kept good time in Paris, lost 2 mins. 28 secs. a day at Cayenne in the West Indies. He explained and confirmed this by showing that the length of a simple pendulum beating seconds at Cayenne was about one-tenth of an inch less than in Paris. Similar results were obtained by Halley at St Helena, and by others at various places near the Equator, leaving no doubt that g varied from place to place on the surface of the earth.

Regarded as an isolated fact, it might well occasion surprise that a quantity that is so obstinately constant at a given place should vary in different parts of the world. This variation was, however, explained by Newton in the *Principia*. He showed that the movements of the heavenly bodies can be explained by his laws of motion if every body attracts every other with a force proportional to its mass and inversely proportional to the square of its distance. He next showed, by a celebrated argument connecting the period of the moon in her orbit with the acceleration due to gravity at the earth's surface, that the force in question is none other than gravity. He then calculated the combined attraction of all the

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Collectively all unusually coloured corundum gems are called fancy sapphires, but those coloured like emerald, topaz, or amethyst have been designated oriental emerald, oriental topaz or king topaz, and oriental amethyst, respectively.

Digitized by Arya Samaj Foundation Chennai and eGangotri

matter in the earth, allowing for the bulging of the Equator due to rotation, and showed that the observed variation of g is just what would be expected. He concluded: 'If this gentleman's [i.e. Richer's] observations are to be depended on, the earth is higher under the Equator than at the poles, and that by an excess of about 17 miles.' Newton's calculation of the variation of g is open to many objections and was vigorously opposed—particularly by the Cassinis, father and son, who maintained, as a result of the measurement of arcs of triangulation in France, that the earth was prolate and not oblate. The matter was finally decided by the measurements made in Lapland and Peru by the French Academy, and even the grandson of Cassini, who, like his father and grandfather, measured arcs in France, was convinced. The theory of the earth's figure was a favourite subject with most of the celebrated applied mathematicians of the eighteenth and nineteenth centuries; among others Clairaut, Euler, Stokes, Kelvin, Poincaré, and G. H. Darwin may be mentioned. As a result of their investigations it is possible to calculate the shape of the earth from gravity observations, and the variation of gravity from the shape. Such calculations confirm Newton's supposition that the earth is very closely an ellipsoid of revolution. The radius from the centre to the poles was found to be 13 miles shorter than that from the centre to the Equator and g to be 0·5 per cent. less at the Equator than at the poles. The polar flattening of 13 miles is almost exactly the amount that would occur if the earth were a fluid; and this suggests that the main bulk of the earth behaves as a fluid to forces lasting for long periods. It is known from the types of waves propagated from earthquakes that, for forces lasting for a minute or so, the earth is solid to a depth of about 2,900 km., and the same thing is shown for forces lasting for about a day by the amplitude of the tide raised by the moon in the earth. It is not at all improbable that the earth should behave as a solid to transient forces and as a liquid to long-lasting ones; similar behaviour is well known in such substances as some sorts of toffee and the stiffer kinds of pitch.

Gravity, measured at the earth's surface, shows local variations, in addition to the regular variation with latitude. Part of these variations is due to differences in height, for the top of a mountain is further from the bulk of the earth than is a place at sea-level, and gravity is consequently less there. This variation is about 1 part in 10,000 for every 1,000 ft. of elevation. After allowing for it, there still remain local variations of up to 1 or 2 parts in 10,000. These variations are due to the different masses of rock lying under different places. The differences are partly due to the visible excesses and deficiencies of hills and valleys, and partly to differences in the densities of the rocks. By a study of these variations or 'anomalies' in gravity, information can be obtained about the distribution of heavy and light rocks, and it is the interest of this geological information that has led to the great extension of gravity measurements in the present century.

Geological structures are complicated, and if gravity is to provide useful information measurements must be numerous. Until about 1920 the method employed for timing the pendulums was essentially the same as that employed by Richer in 1672. The pendulums were timed by a clock which was rated by observations of the stars with a transit instrument. This is a time-consuming procedure requiring fine weather for several nights in succession, and it was unusual for an observer using it to make more than a dozen measurements in a year. With the introduction of wireless time-signals the work was greatly speeded up and became independent of the weather. The regular time-signals are, however, rather infrequent, and several observers have transmitted special signals for their measurements, often controlled by a pendulum similar to that used at the station at which g is being measured. The use of time-signals can be avoided altogether by recording an ordinary Morse message simultaneously at a fixed station and at the place where g is being measured. At each station the message is recorded alongside a record of the swings of a pendulum. The dots and dashes of the Morse message then mark a series of simultaneous instants at the two places and enable the periods of the two pendulums to be compared. Figure 2 shows the apparatus in use in the Belgian Congo.

By such methods it is possible to reduce the time required for a measurement to about an hour, but the time required for the transport, fitting up, and dismantling of the bulky and rather complicated gear still limits the rate of progress, and it is difficult to average two stations a day. In order to avoid these difficulties a number of workers have abandoned the pendulum and devised spring balances for measuring g. In principle this method is very simple: a weight hung on a spring extends it until the restoring force is equal to the force exerted by gravity on

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

the weight. If the balance and weight are taken to a place where gravity is greater, the force on the weight will be greater and the spring will be further extended. In practice it is difficult to produce a spring that will remain sufficiently constant, and the most successful designs are trade secrets of prospecting firms. With such instruments measurements can be made in a few minutes and the variation of *g* mapped in detail in a way that would be impossible by the older methods. Owing to the slow drift of even the best springs, it is necessary for a gravity survey with a spring balance to be connected to the rest of the world's gravity network by measurements made with pendulums.

The methods described above provide satisfactory measurements on land; but, as two thirds of the earth's surface is covered by sea, the information obtained will give a very one-sided picture of the earth's gravitational field. The problem of measuring *g* at sea is one of great difficulty, as there is no fixed point and no way of completely separating the ship's accelerations from gravity. In addition, the rolling and pitching of the ship hopelessly disturb any ordinary gravity-measuring apparatus. The problem has been solved by the Dutch geophysicist Vening Meinesz, who employs an ingenious combination of pendulums which very nearly eliminates the effects of small motions of the support of the apparatus. In order to bring the motions below the limit where this elimination is satisfactorily performed, it is necessary to work in a submarine submerged to such a depth as greatly to reduce the wave motion. Figure 3 shows the apparatus installed in an American submarine. In a series of journeys in Dutch submarines Meinesz has made over 1,000 measurements in the Atlantic, Indian, and Pacific Oceans, particularly in the seas around the East Indies. Measurements have been made in the West Indies in United States submarines, and a start was to have been made in 1938 in a submarine of the British Navy. The British work was stopped by the Munich crisis after only two measurements had been made.

Though our knowledge of the earth's gravitational field is still very incomplete and vast areas are left entirely unsurveyed, certain general features have appeared. The most striking of these is the apparent lack of gravitational attraction from mountains. This was first noticed in the middle of the eighteenth century, when one of the French academicians observing an arc of the meridian in Peru measured *g* on Chimborazo. This isolated observation did not attract much attention, and general interest was aroused only when the measurements of Sir George Everest and the calculations of Archdeacon Pratt of Calcutta (figure 4) showed that the Himalayas deflected a plumb-bob in the Ganges plain much less than would have been expected from their size and density. The Archdeacon explained this unexpected result by suggesting that the mountains are underlain by less dense rocks than the neighbouring plains, the deficiency in density being just enough to cause the total mass per unit area to be the same everywhere. That is to say, the excess mass of the mountains is balanced by a deficiency beneath them, a state of affairs called isostasy. It is exactly the condition that occurs with a floating iceberg, where the visible mass above sea-level is exactly equal to the deficiency of mass below, due to ice displacing the heavier water. This analogy suggests that the explanation of Pratt's result is that the mountains have a subterranean 'root' of light rock and that the mountain and root are together floating in hydrostatic equilibrium on the rocks beneath the crust. The rocks at a depth of 40 km. or so must therefore be liquid in the sense that they cannot indefinitely sustain a shearing stress. As was pointed out when discussing the figure of the earth, this is not inconsistent with their being at the same time 'solid' for forces lasting for a short time.

The consequences of isostasy have been worked out in great detail, particularly by Hayford and Bowie of the United States Coast and Geodetic Survey, and it is now known that not only the Himalayas but the Alps, the Rocky Mountains, the African Plateau, and many lesser features are in isostatic equilibrium. The Atlantic Ocean is roughly in equilibrium, that is to say it is underlain by enough dense rock to compensate for the lightness, relative to normal rocks, of the water overlying it. The compensation is, however, slightly overdone, and over large areas in the North Atlantic gravity is in excess of what would be expected if there were isostatic equilibrium. This excess implies deep-seated stresses, but too little is known of the geology of the Atlantic Ocean for a convincing explanation to be given as to why these exceptionally widespread anomalies occur there. Still more striking departures from isostasy occur near the ocean deeps fringing the arcs of islands in the East and West Indies (*see* figure 1) and off Japan. These anomalies occur along narrow lines parallel to the axes of the deeps, and consist of a strip of deficient gravity

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

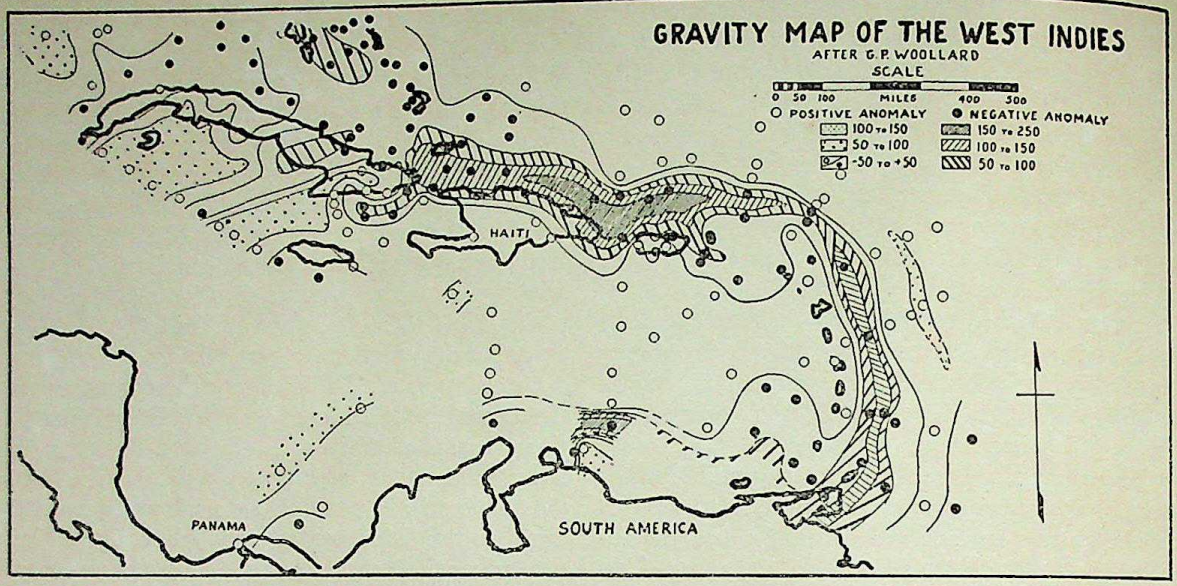


FIGURE 1 – *The gravity anomalies in the West Indies. The unit is* 10^{-3} *cm./sec.*^{2} (*Proc. Amer. Philosoph. Soc.*, 1938, 79, 62.)

bordered by broader but less intense strips of positive anomalies. Meinesz, who discovered these strips, has explained them as due to a body of light crustal rocks buckled downwards by horizontal thrusts. The East Indian line of anomalies forms a continuation of the line of the Himalayan mountain system, and there has been much speculation as to the relation of the deeps, their associated gravity anomalies, earthquakes, and volcanoes to mountain-building processes. It is possible that in these areas we have a mountain-building process which has not come to fruition owing to the absence of a sufficient supply of sediment.

In recent years many other striking exceptions to the general rule of isostasy have been found, particularly over the East African Rifts and in the Ferghana basin on the north-west side of the Himalayas. It is not possible in a general article to discuss these in detail, though their relation to the local geological structures is of great interest. The tendency during the last ten years has been towards a closer connection between traditional geology and geophysical investigations such as gravity measurement; this appears not only in the broader problems discussed above but also in the application of geophysical methods to the smaller scale geological problems of the oil prospector and the mining engineer. There is no doubt that there is a large field of interesting and useful work to be explored as soon as conditions allow.

'Weighing the earth'

Closely allied in interest to the study of the Earth's gravitational field is the problem of the determination of the Earth's mean density or, what amounts to much the same thing, the determination of the mass of the Earth, a process popularly, and inaccurately, described as 'weighing' the Earth. Newton came very near to the truth in his statement: 'It is probable that the quantity of the whole matter of the Earth may be five or six times greater than if it consisted all of water,' and the verification of this famous guess forms one of the most fascinating tales in the history of experimental physics. The trouble arises from the relative smallness of the forces involved. One may combat this difficulty by measuring the deflection of a plumb-line caused by a large natural mass such as a mountain and so compare the mass of the mountain with that of the Earth, but this merely minimizes one difficulty at the expense of introducing another—that of determining the mass of the mountain with any reasonable approach to accuracy. Results of the highest precision are obtained by experiments on smaller and more exactly measured masses. Thus Cavendish at the end of the eighteenth century and Boys at the end of the nineteenth century measured the deflection of a torsion balance caused by lead spheres, and Heyl has recently investigated the effect of the proximity of large cylindrical masses on the period of vibration of a torsion balance. Poynting weighed a mass of some 20 kg. on a large bullion balance; he then brought close beneath this mass a large sphere having a mass of about 150 kg. and measured accurately the small increase in weight of the 20 kg. due to the attraction of the larger sphere.

The results of these experiments are all within the range of Newton's guess. The mean density of the Earth is almost exactly 5·5 times that of water.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

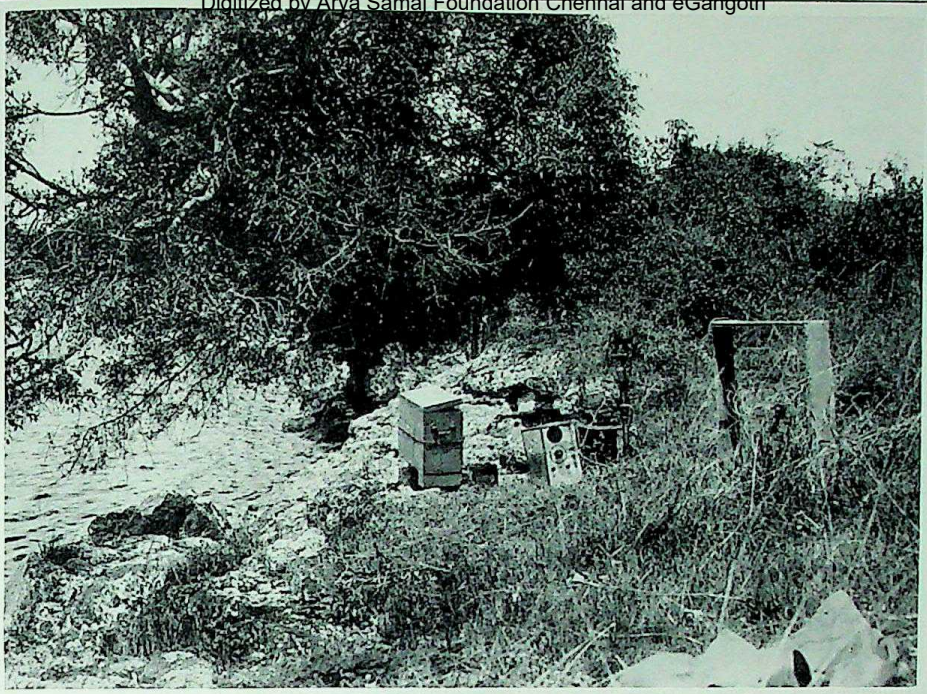


FIGURE 2 – *Pendulum apparatus on the shores of Lake Kivu in the Belgian Congo. The box on the left is the chronograph for recording the wireless signals and the swings of the pendulums; the pendulums are swung in the black box. The wireless set, with its frame aerial, and the pump for evacuating the pendulum box, can also be seen.*

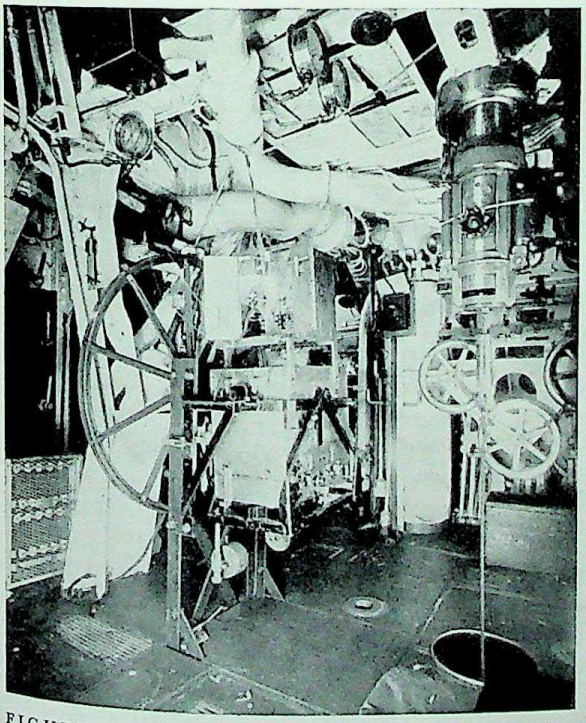


FIGURE 3 – *The gravity apparatus mounted in the United States submarine S-21.* (*United States Navy official photograph.*)

FIGURE 4 – *Archdeacon Pratt as a young man.*
(*From a drawing in the possession of Caius College, Cambridge.*)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

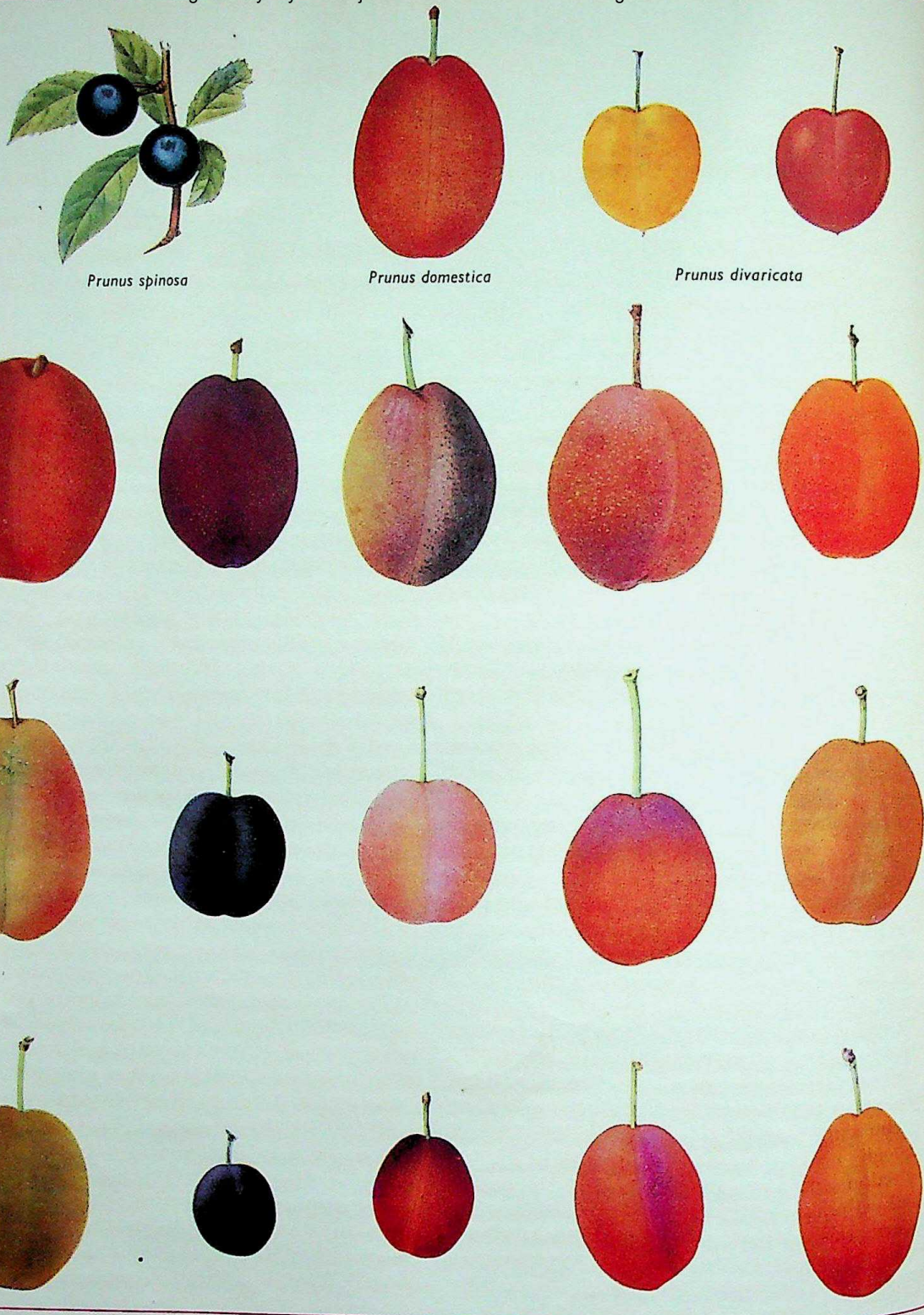


FIGURE 4 – *Plums of the past and of the present.* (*Top row*) *The blue sloe,* Prunus spinosa (*thirty-two chromosomes*), *the yellow-red myrobalan or cherry-plum,* Prunus divaricata (*sixteen chromosomes*), *and the European plum,* Prunus domestica, *var. Victoria* (*forty-eight chromosomes*), *which is derived from their hybrid by doubling the chromosome number.* (*Below*) *The fruits of fifteen seedlings produced by self-fertilizing the Victoria variety to show how the ancestral colours, shapes, and sizes can be segregated and recombined to prove the origin of a cultivated plant two or three thousand years ago.* ($\frac{5}{8}$ *nat. size.*) (*Paintings by the late H. C. Osterstock.*)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Cultivated plants of the past, present, and future

M. B. CRANE

Even a slight improvement in a crop may amount to huge sums in the economy of a nation. In the following pages Mr Crane tells how many important cultivated plants have come about, what their ancestors were, how new cultivated plants are continuing to arise spontaneously, and how they can now be produced at will. He also shows that the science of genetics is indicating methods of getting better crops from the plants we already have.

Most of our cultivated plants have been under culture from very early times and the manner of their origin is often little known. For centuries, selection was the only method used to improve them, and natural seedlings of selected plants were the only material from which selection was possible. In these early times selection therefore operated on the maternal side only; the pollen came by chance from other individuals and there was no control of the paternal parent.

The discovery of sex in plants, in the eighteenth century, meant the realization that the male parent is as important as the female parent. This gave some impetus to the breeding of plants, but it was only after the rediscovery of Mendel's papers towards the end of the nineteenth century that the full possibilities of plant-breeding became apparent. During the present century the concept of the gene as the unit or 'atom' of inheritance, and the identification of the chromosomes as strings of genes, have put the whole matter in a new light. More recently, modern methods of research, a combination of genetics, cytology, and chemistry, have already shown how many of our present-day cultivated plants have originated, what their ancestors were, and how new and improved plants may be obtained for cultivation in the future.

Our cultivated plants have had four distinct, though often overlapping, modes of origin: by selection with and without species-hybridization, and with and without chromosome doubling. Of course, selection is much quicker with hybridization than without it; and with chromosome doubling the new types are produced *per saltum*—they result from a doubling of the chromosome number by failure of a nuclear division, and recent research has shown how this can be brought about at will (Darlington, 1942).

The part that selection without species-hybridization has played in the origin of new plants is evident from the many new varieties and forms which have appeared even within living memory. The sweet-pea, for example, was widely cultivated fifty years ago, but at that time no great range of varieties existed. Since then not only has the range of colour been vastly extended, but large differences have appeared in habit of growth, structure of leaves, and flowers. Indeed, the more attractive Spencer form of flower with erect, large, waved petals has completely ousted the old hooded form from cultivation. Thus the sweet-peas grown today are as distinct from those grown at the beginning of the present century as were the latter from the sweet-peas first grown in England from the seed sent by the Sicilian monk Franciscus Cupani in 1699. Similar remarks apply to the tomato, the raspberry, the edible pea and a vast number of other plants. Such new varieties of plants have resulted spontaneously by gene-mutations.

Gene-mutations have also been responsible for some remarkable plants commonly found in cultivation. Most plants, from the standpoint of genetics and inheritance, are the same all through. Consequently, when they are propagated vegetatively, it does not matter which tissue—stem, root, tuber, etc.—is used to start the new individual, or whether the tissue originates from the inside or outside of the plant: the resulting offspring are always the same, and if they are established varieties they generally reproduce themselves from seed. But there are surprisingly large numbers of plants which do not possess this uniformity or individuality and, when they are propagated, different tissues give rise to different types of offspring. Such plants are composed of

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

two or more genetically distinct tissues and can be classified according to the way in which these different tissues are arranged and grow. In a common type, one genetic type or variety surrounds another, just as a glove covers a hand. Most of these plants have arisen by gene mutations occurring in the body tissues in such a way that only certain layers of the cells which go to make up the plant are affected by the change. Now, many of these plants can be propagated by root cuttings, and by adopting this and kindred methods their exceptional make-up has been demonstrated, for buds from roots usually arise from the internal tissues. Thus Bateson (1916) found that root cuttings of the pink-flowered Bridesmaid variety of *Bouvardia* produce the red-flowered variety Hogarth.

Many varieties of potatoes are of the same class, and their structure was first demonstrated by Asseyeva in Russia (1927) by a slightly different but equally simple method, viz. by removing the eyes of the tubers and thus stimulating the internal tissues below the excised eyes to form buds. A British variety known as Golden Wonder, which has a thick brown russet skin, contains internally the variety Langworthy, which has a thin white smooth skin (Crane, 1936) (*see* figure 1). Such plants often present a problem to the plant-breeder, for the external glove-like variety may have a thickness of one or more cell layers. Now the reproductive cells are generally formed from the sub-epidermal or second layer; hence the germ-cells—the egg-cells and the pollen—will be of the kind of which this layer is composed. Thus the thick brown russet skin character of the potato Golden Wonder is genetically only skin deep; consequently the germ-cells are all Langworthy, and in sexual reproduction the russet character is not passed on and the offspring are all smooth. Langworthy was known before 1876 and Golden Wonder was first distributed in 1906.

Though often used by breeders to produce new varieties by recombination, gene-mutations are not themselves directly due to hybridization. Nor, as is frequently supposed, are they due to the direct effects of cultivation, though indirectly cultivation has had important effects, (*a*) on account of the close in-breeding involved, which reveals mutations latent in the stock; (*b*) on account of selection and/or vegetative reproduction, which maintain these mutations as distinct strains; and (*c*) on account of the protection which cultivation affords to the less robust types. Another important result of culture is that geographical and ecological barriers are commonly overcome; species distantly separated in nature are brought together and opportunities are provided for hybridization, which, as we shall see later, has led to important developments.

The second mode of origin, a simple doubling of the chromosome number, has yielded, and is continuing to yield, many new plants. Most varieties of raspberries have fourteen chromosomes, but Belle de Fontenay, Merveille Rouge, and several others have twenty-eight. The twenty-eight-chromosome kinds are autumn fruiting varieties; they have arisen from the fourteen-chromosome summer fruiting varieties during the past eighty years. In the Chinese primula there are varieties with twenty-four chromosomes and others with forty-eight. The latter are giant forms with large flowers and arose from the twenty-four-chromosome forms spontaneously at the beginning of the present century. In pears a new giant form, the first of its kind, recently arose in the nurseries of Messrs W. Seabrook (England). It has twice the usual number of chromosomes, namely sixty-eight instead of thirty-four, and its fruits are of better quality and about twice the size and weight of the variety from which it came (Crane and Thomas, 1939) (*see* figure 2). These are examples of new races of plants which have arisen in very recent times from a complete duplication of the chromosome number. Sometimes, as in *Primula*, they have come about through the sexual process, the germ-cells having had a double number of chromosomes; and sometimes, as in the pear, vegetatively, a double number of chromosomes occurring in the somatic or body-cells.

Normally all the body-cells of a plant have a fixed number of chromosomes, which by a special cell-division give germ-cells with only half the number (cf. Darlington, 1942). Many valuable plants have arisen from the failure of this division in forming one of the parental germ-cells. Plants arising in this way have one and a half times as many chromosomes as their parents and not twice as many as in the new primulas and pears. Thus apples are of two kinds: some have thirty-four chromosomes (two lots) and others fifty-one chromosomes (three lots). The latter arose from the union of a normal germ-cell with seventeen chromosomes and a germ-cell with a double lot, thirty-four. Some of the most important apples in the world are in the fifty-one-chromosome class. Amongst them are Bramley's Seedling, the most widely grown apple in England; Belle de Boskoop, the most popular apple on the continent of

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

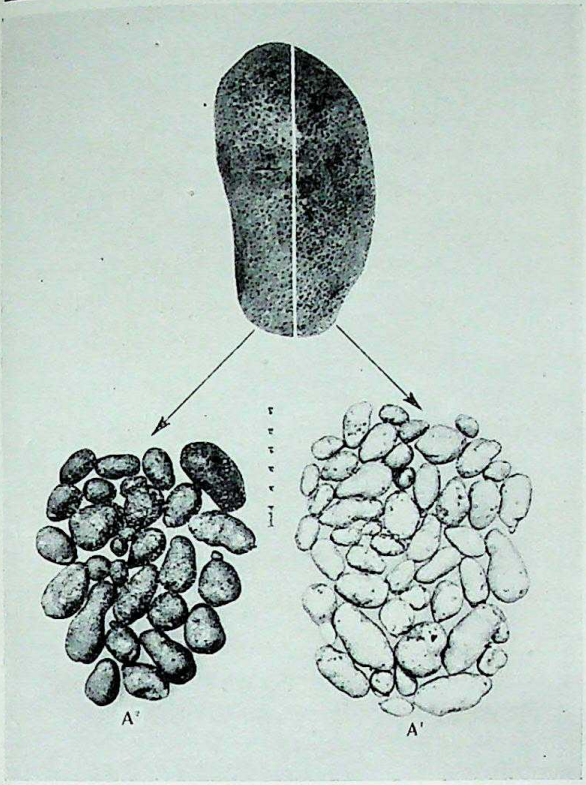
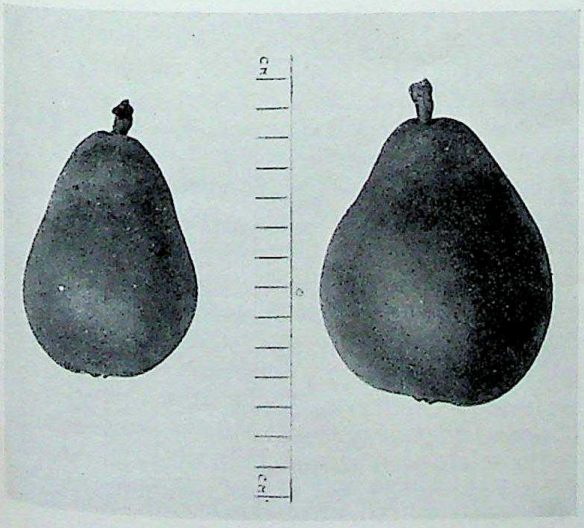
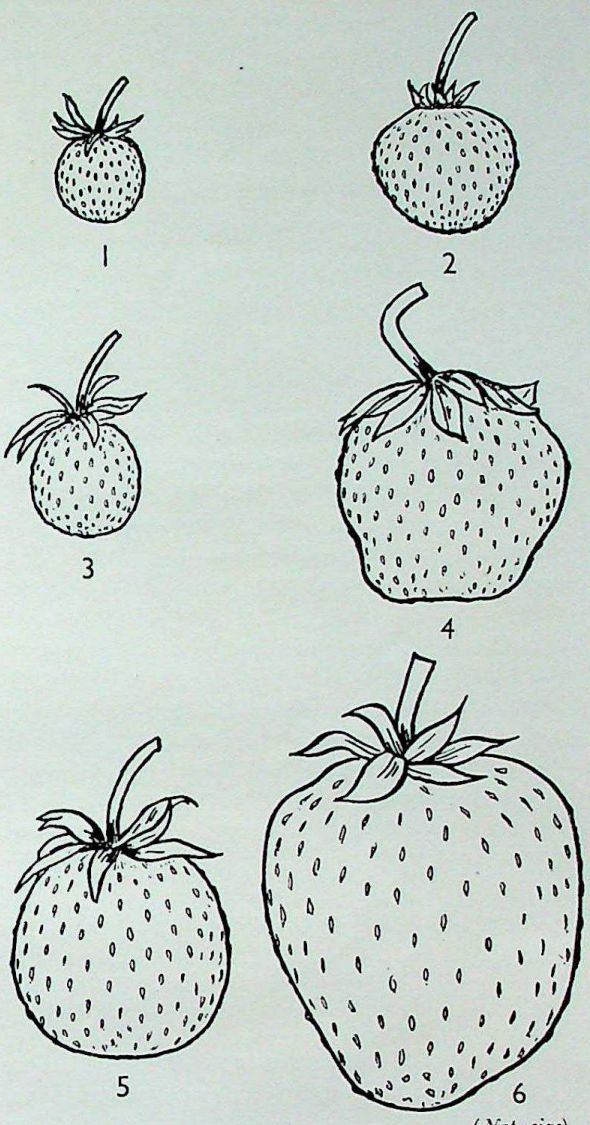


FIGURE 1 – Two varieties or one? *The potato Golden Wonder (above) was cut into halves. In one half the eyes were removed so that buds were induced to form from the internal tissues below the excised eyes. This half was planted and gave tubers of the variety Langworthy as shown on the right, A^1. The other, untreated, control half gave tubers all Golden Wonder, A^2. Many cultivated plants, including other potatoes, have this remarkable make-up, and by a simple surgical operation it is possible to plant one variety and dig up another.* (*From* Journal of Genetics, **32.**)





(*Nat. size*)

FIGURE 3 (*above*) – Strawberries of the past and of the present.

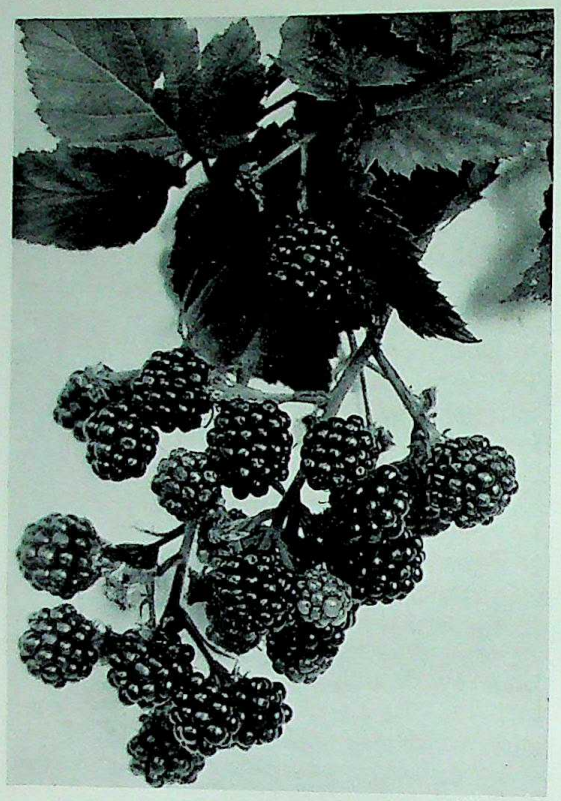
		Chromosome number	*Period*
1.	*Fragaria vesca*	14	1300–
2.	*Fragaria elatior*	42	1500–
3.	*Fragaria virginiana*	56	1600–
4.	*Fragaria chiloensis*	56	1700–
5.	Keen's Seedling	56	1821–
6.	Royal Sovereign	56	1892–

'Strawberries ripe!' was a familiar cry in the streets of London four centuries ago. At that time the tiny fruited Fragaria vesca *was the principal species in cultivation.*

FIGURE 2 (*left*) – Pears of the present and of the future. (*Left*) *The pear Fertility; this variety has thirty-four chromosomes and was raised in* 1875. (*Right*) *Fertility Improved, the first of its kind with sixty-eight chromosomes. It arose in* 1933 *by the occurrence of chromosome doubling in a somatic cell. Its fruits are of better quality and much larger than those of the variety Fertility from which it came.* (*From* Journal of Genetics, **37.**)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri



($\frac{1}{2}$ *nat. size*)

FIGURE 5 – Blackberries of the future. *The blackberry Merton Thornless, entirely without prickles, was raised by the author by crossing two native British species of blackberries. (Photograph by R. A. Malby.)*

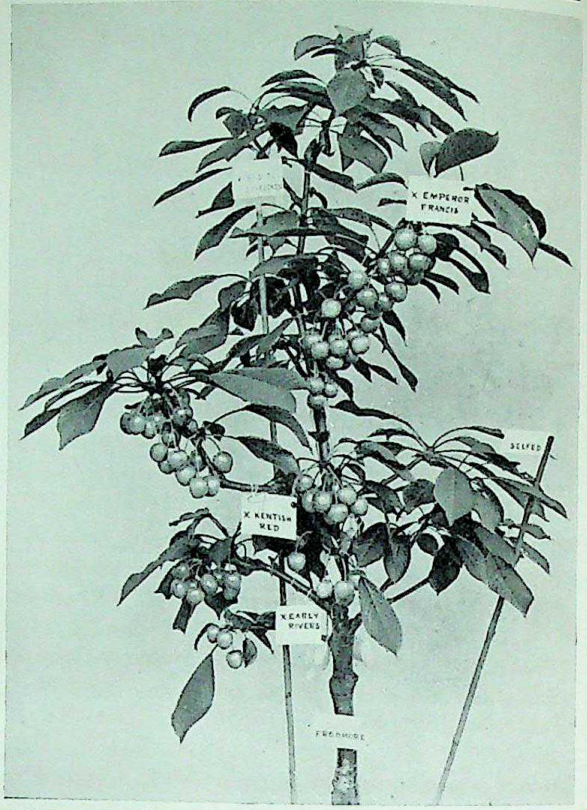
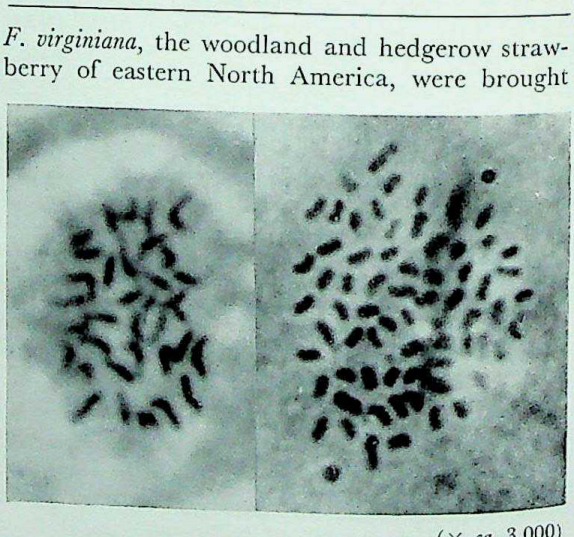


FIGURE 7 – To obtain a crop of fruit it is necessary to plant fruit trees in the right company. *The cherry Bigarreau Frogmore. (Right) Self-pollinated: no fruit set. (Top) Pollinated with Bigarreau de Schrecken: no fruit set. The remainder of the tree, pollinated with inter-fertile varieties, has given an abundant crop.*

Europe; and Baldwin, the standard winter apple of Eastern America.

Plants with more chromosomes have more genes, and this has important effects on individual characters. Thus there is a gene, Y, for yellow colour in maize, which is associated with vitamin A. Mangelsdorf and Fraps (1931) found that plants with 0, 1, 2, and 3 Y genes had an average of 0·05, 2·25, 5·00, and 7·5 units of vitamin A per gram respectively, and in apples the highest vitamin C content is found in the fifty-one-chromosome varieties (Crane and Zilva, 1931).

The development of the garden strawberry shows how new plants have come about by the third mode of origin, viz. by selection from the offspring of species-crosses without the direct intervention of chromosome doubling. The cultivation of the strawberry in Europe goes back to the fourteenth century. At that time only the wild wood strawberry, *Fragaria vesca*, was grown under cultivation. *F. elatior*, found sporadically in the woods on the continent of Europe, and *F. virginiana*, the woodland and hedgerow strawberry of eastern North America, were brought



(× *ca.* 3,000)

FIGURE 6 – Creating new plants by chemicals. *(Left) A normal cell of the apple Heusgen's Golden Reinette, with thirty-four chromosomes; and (right) a cell of the same variety after treatment with the drug colchicine, with sixty-eight chromosomes. (Photograph by Dr P. T. Thomas.)*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

into cultivation in the sixteenth and seventeenth centuries respectively. The fruits of all three species are small, and at that time no appreciable increase in the size of fruits had occurred under cultivation. Early in the eighteenth century a fourth species, *F. chiloensis*, with large fruits, was introduced into Europe from South America. *F. chiloensis* is a dioecious species, i.e. its male and female flowers are on different plants. Unfortunately all the plants introduced were female, and for a long time, owing to the absence of pollen, no fruit was obtained from them. Later some of the plants were grown near other strawberries such as *F. elatior* and *F. virginiana*. These pollinated the *chiloensis* plants and satisfactory crops developed. The fruits though large were poor in colour and quality, but seeds from them, the result of crossing with *F. virginiana*, were the beginning of our modern race of strawberries. The first varieties of this type, combining the larger size of *F. chiloensis* with the aromatic qualities of *F. virginiana*, appeared in France towards the end of the eighteenth century. It was not, however, until the early part of the nineteenth century that any considerable progress was made. At this time the English horticulturists took the lead and the advance they made was due to the raising of plants from seed and deliberate cross-breeding. Landmarks in the development of the garden strawberry are the varieties Keen's Imperial (1806) and Keen's Seedling (1821), raised by Michael Keen of Isleworth; and Black Prince (1822) and Wilmot's Superb (1823), raised by a Mr. Wilmot, also of Isleworth. There is evidence that Keen's varieties were natural crosses and Wilmot's varieties deliberate crosses between *F. chiloensis* and *F. virginiana*. Elton Pine (1827) was raised by Thomas Andrew Knight; British Queen (1840) by Myatt of Deptford; and Sir Joseph Paxton (1862) by Samuel Bradley of Nottingham. The most successful of the English breeders, however, was Thomas Laxton of Bedford. He raised many notable varieties from about 1870 and introduced his world-famous Royal Sovereign in 1892.

In recent years the genus *Fragaria* has been critically studied and the chromosome number of the different species determined. The details given in figure 3 make the story clear. Experiments have shown that crosses between the species with different chromosome numbers (*see* figure 3), such as *F. vesca* × *F. elatior* and *F. elatior* × *F. virginiana* or *F. chiloensis*, are abortive or result in sterile hybrids, but crosses between species with the same chromosome numbers, such as *F. virginiana* × *F. chiloensis*, result in fertile offspring. Thus the development of the strawberry subsequent to the introduction of new species into Europe depended on the hybridization of the two fifty-six-chromosome species which until then had been geographically isolated.

We now come to our last and most important mode of origin, viz. species-hybridization accompanied by chromosome doubling. Our cultivated plums, *Prunus domestica*, have arisen from hybridization between the small cherry-plum *P. divaricata* and the still smaller sloe *P. spinosa*. The cherry-plum has sixteen chromosomes and the ground or granular colour of its fruit is yellow, while the anthocyanin or sap colour is red. In the sloe, which has thirty-two chromosomes, the ground colour is green and the anthocyanin blue, and the range of variation in both species is limited. In the cultivated plum both red and blue colours and yellow and green grounds occur, and from their various recombinations an infinitely wider range of variation results. Such a range can be obtained by self-fertilizing a single variety like Victoria (*see* figure 4). Normal hybrids between the two ancestral species have twenty-four chromosomes and are highly sterile. Such hybrids are still found in the forests in the North Caucasus (Rybin, 1929). The cultivated plums have forty-eight chromosomes, i.e. twice as many, and are highly fertile. They have larger fruits with a wide range of form and flavour (Crane and Lawrence, 1920–38). These facts all substantiate the view that the cultivated plum arose from hybridization between the cherry-plum and the sloe, accompanied by chromosome doubling.

Combined genetical, cytological, and chemical investigations by Lawrence and Scott-Moncrieff (1929–35) have shown that, with the exception of the garden dahlia, all the species of *Dahlia* fall into two groups for flower colour, one with magenta and the other with scarlet or orange flowers, and with one exception they all have thirty-two chromosomes. The anthocyanins in the magenta group are cyanidin types, and those in the scarlet group are pelargonidin types (Robinson, 1942). Variation within these species, of which there are over a dozen, is very limited. The magenta species may give ivory-white and the scarlet species yellow varieties. *Dahlia variabilis*, the garden dahlia, combines the pigments of the two groups. It also has twice as many chromosomes—sixty-four instead of thirty-two—and experiments convincingly led to the conclusion that *D. variabilis*, with its wide range of colour

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

and form and great increase in flower size, arose from hybridization and chromosome doubling between species in the magenta group and species in the scarlet group.

Figure 5 shows the blackberry Merton Thornless. Its great-grandmother, from which its thornless character was derived, was *Rubus rusticanus inermis*. Its great-grandfather was *R. thyrsiger*, a native of Devon. *R. rusticanus* is the common hedgerow blackberry of southern England, though its thornless form is rare. Merton Thornless is more vigorous, and has much larger fruits and twice as many chromosomes as its thornless ancestor (Crane, 1938).

Brassica oleracea—the cabbage, brussels sprouts, and cauliflower group of *Brassica*—has eighteen chromosomes. *B. rapa*, the turnip group, has twenty. The swede (*B. napo-brassica*) and the vigorous kale group (*B. rapa-oleracea*) have thirty-eight (Thomas and Crane, 1942). The latter are composed of double hybrids from the other two—and so we could go on with our story and show how many more trees and plants, including our bread-wheats and oats, have originated in a similar way, how they excel their ancestors, and how these occasional 'accidents' in the course of reproduction have bestowed enormous benefits on mankind.

The crossing of distantly related plants has been done ever since the discovery of sex in plants, in order to bring desirable characters together. This is not difficult, but like the cherry-plum × sloe crosses, the hybrids thus created are usually sterile and hence of little value. In the past we have had to await the rather rare 'accident' of spontaneous chromosome doubling for the restoration of fertility and the production of desirable new forms. It is at this point, by providing the plant-breeder with new tools with which he can induce 'accidents' of this kind at will, that science is now directly lending a hand. One such new tool, amongst others, is the discovery in America about five years ago that the drug colchicine, when suitably applied to plants, will induce chromosome doubling. In this way already a number of sterile species hybrids have been made fertile. More recently, in Russia, it has been found that acenaphthene can be used for the same purpose.

Already in America it is possible to buy seeds of plants with double the normal number of chromosomes, the result of colchicine technique, and with more experience and adjustment of the technique to suit particular plants, it seems safe to predict that we shall soon have further races of improved economic plants, which in time will displace many of those now cultivated. Figure 6 shows a normal thirty-four-chromosome cell from a growing point of the apple Heusgen's Golden Reinette, and a cell of the same variety after treatment with colchicine, with sixty-eight chromosomes.

Genetical science is also showing the way to get better crops from the forest, farm, and garden plants we already have in cultivation. When two in-bred strains or varieties of plants are crossed together it commonly happens that the first hybrid generation is more vigorous than either of its parents. Such increased vigour is often accompanied by a higher yield and other economic advantages, and in plants so diverse as maize and forest trees this hybrid vigour has been turned to great profit. In maize it has been utilized in America on a gigantic scale, and a number of hybrid strains have been introduced for general cultivation both from experimental stations and from commercial seed companies. In addition to giving great increases in yield, hybrid generations have been found which are more uniform, and more able to withstand drought, wind, diseases, and other unfavourable conditions, than the best standard varieties; as a consequence the acreage of hybrid maize grown in America has doubled or trebled every year during the past few years, and in 1939 over 20,000,000 acres were planted with hybrid seed. Though the old kinds have to be retained, this type of maize, raised anew each year from controlled crossing, is therefore rapidly displacing the older standard kinds in cultivation.

Though naturally slower, the utilization of hybrid vigour in forest trees has given decisive results in America and Sweden. The Forestry Commission in Great Britain has a £41,000,000 post-war plan which will no doubt include breeding investigations.

There is an entirely different way in which we are improving the productivity of our orchards. Our fruit trees are all propagated by grafting, and all the trees of each variety are therefore parts of one individual. Most of them are self-sterile, and many inter-sterile (*see* figure 7). For example, varieties in the sweet cherries fall into groups within which all pollinations between the different varieties are useless (Crane and Brown, 1937). This behaviour is controlled by less than a dozen genes, and if a crop is to be obtained it is necessary to follow the fertility rules they dictate, by planting suitable inter-fertile varieties together.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The aether: past and present

E. T. WHITTAKER

Space devoid of matter can still transmit gravitational and electromagnetic forces, a fact from which it is natural though perhaps philosophically artless to assume a medium of transmission—the aether. Professor Whittaker shows that all theories of the constitution of the aether are unsatisfactory, but that this negative knowledge is not without its value.

By means of the modern diffusion pumps it is possible to obtain in the laboratory a 'vacuum' with a pressure of 10^{-12} atmospheres or even less, that is, a condition in which there are only about $3 \cdot 10^7$ molecules per cubic centimetre of air. In interstellar space the rarefaction is of a much higher order—perhaps one atom or molecule per cubic centimetre, and in some regions of the universe still fewer. But however far exhaustion may be carried, and even if every atom of matter could be removed from a region of cosmic size, we have every reason to believe that we should never obtain mere non-entity. Space has at all times and everywhere the properties of being able to transmit gravitational and electromagnetic forces, and of supporting the propagation of light; and these properties seem to imply that, however extreme the vacuity, there is always still *something there*.

What is this something? It has at any rate a name: it is called the *aether*. Innumerable constitutions have been proposed for it, but the net result of twenty-five centuries of natural philosophy has been to discredit every one of them. However, negative knowledge—what the aether *cannot* be—is not without its value, since it narrows and clarifies the field for investigation in the future.

The first conjecture we can make is that in addition to the molecules of matter and protons and neutrons and mesons and electrons that we know about, the universe contains vast numbers of other particles, hitherto unrecognized by physical tests: particles much smaller than atoms, or even than electrons, and capable of passing freely through ordinary solid matter. Obviously the processes so far devised for obtaining a vacuum by exhaustion, although they remove the material molecules, would not remove these other particles. An analogy may be drawn from bacteriology, where in addition to the bacteria which can be detected by the microscope, there are viruses which cannot be identified in this way and which pass readily through filters.

Now it is a fact that within recent years some fairly strong evidence for the existence of unperceived particles has become available. In the β-ray disintegration of a radio-active substance, it is found that the β-particles emitted by different atoms of a given element are emitted with energies varying over a considerable range, in contrast with the α-radiation, for which the α-particles always possess fixed energies. For every β-radiation there is a definite *maximum* energy for the β-particles, but the velocity of a particle may have any value less than that which corresponds to this energy: the β-radiation has a *continuous* spectrum.

This well-attested fact of observation creates difficulties with regard to the conservation of energy; for the atomic nuclei from which the β-rays are expelled can exist only in discrete fixed states, and it would seem, therefore, as if the atom and β-particle together after emission cannot in *all* cases have an energy equal to that of the atom before emission. The conservation law does in fact hold only for the upper limit of the β-spectrum. Pauli in 1931 proposed to overcome this difficulty by postulating the existence of a new kind of particle, the *neutrino*, having (i) no charge, (ii) a small or zero proper-mass, and (iii) a spin angular-momentum of $\frac{1}{2}\hbar$[1]. The neutrino is emitted at the same time as the β-particle, and carries away energy and momentum in such amounts as to ensure that the conservation laws are satisfied in the whole process. The neutrino-radiation, by reason of its enormous penetrating power, would be very difficult to detect observationally.

Further evidence for the existence of the neutrino in the β-emission is furnished by the principle of conservation of angular momentum (which

[1] $\hbar$ is $\frac{h}{2\pi}$, where h is Planck's 'quantum of action.'

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

requires that another particle must be emitted at the same time as the electron, and that this particle must have spin $\frac{1}{2}\hbar$), and by experimental determinations of the recoil of the nucleus, from which it appears that the laws of momentum as well as those of energy indicate the presence of a third particle in the process.

The neutrino plays a considerable part in the recent theory of the meson, and has been invoked by astrophysicists in order to explain the phenomena of 'new' stars. Though still unobserved, it is now generally accepted as one of the elementary particles of the universe.

This recently acquired piece of knowledge invests with some interest one of the oldest aether theories, namely Le Sage's *theory of ultra-mundane corpuscles*. Le Sage, a French Swiss, whose life extended over most of the eighteenth century, devoted sixty-three years to perfecting an explanation of gravitation. He supposed an infinite number of very small corpuscles, like neutrinos, to be moving in space in all directions with exceedingly great velocity, being so sparsely distributed (that is to say their diameters are so small relatively to their mean mutual distances) that not more than one out of every hundred of them meets another corpuscle during millions of years. If only a single particle of ordinary matter existed in the universe, it would remain at rest, since the momenta communicated to it by the corpuscles would be equal in all directions. But two particles of ordinary matter would to some extent screen each other, each particle receiving fewer impacts on the side facing the other than on the reverse side. The two particles would therefore be impelled towards each other with a force which, as Le Sage showed, would vary inversely as the square of their mutual distance.

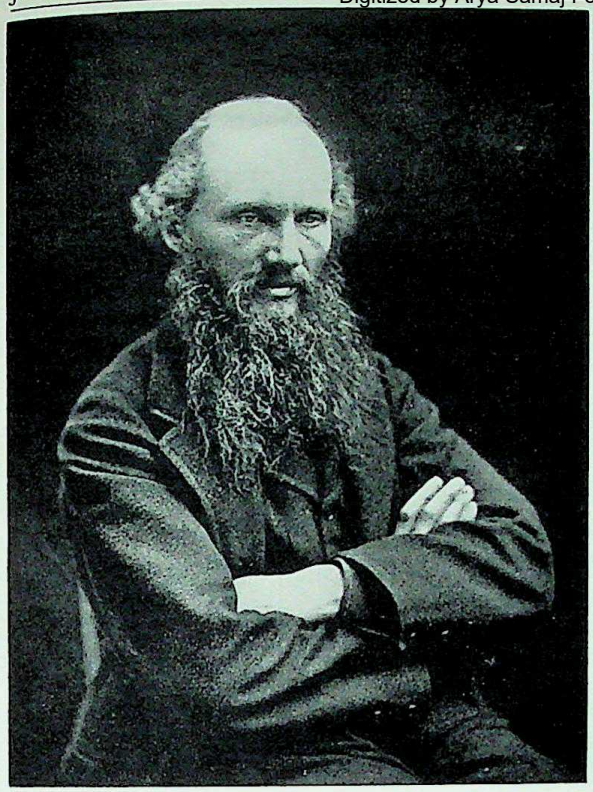
Gravitation is, however, only one of the types of action which seem to require an aether for their explanation; and even before the discovery of the Newtonian law aethers had been devised to account for the propagation of light. In the *Dioptrique* of Descartes, which was published in 1638, interplanetary space is supposed to be occupied by a closely packed assemblage of very small globules, which are pressed in contact with each other, the transmission of this pressure constituting light. Vision is thus compared to the perception of the presence of objects which a blind man obtains by the transmission of pressure along his stick from an object to his hand. This conception was rejected in Hooke's *Micrographia*, which was published in 1667, in favour of the hypothesis that the condition associated with the emission of light by a luminous body is a rapid vibratory motion of very small amplitude which excites vibrations in an aether. Newton, as is well known, was impressed by the difficulty of reconciling a theory of aethereal vibrations with the rectilinear propagation and polarization properties of light; and he put forward conjecturally (though with hesitation) the supposition that rays of light are streams of corpuscles emitted by luminous bodies, while at the same time he retained Hooke's doctrine that the actual emission of the rays is due to a violent motion of an aether in the incandescent substance.

Those natural philosophers of the seventeenth and eighteenth centuries who adhered to the wave theory of light generally assimilated it to the propagation of sound in a gas, and were inclined to picture the aether as a kind of gas permeating all bodies and filling interplanetary space. But, for the vibrations of sound in air, the direction of vibration is the same as that of propagation: whereas it was discovered by Thomas Young in 1817 that the vibrations of light are executed at right-angles to the direction of propagation, like the undulations of a cord agitated by one of its extremities. Thus the analogy between sound and light was seen to break down in an essential feature. Some change in the conception of the aether was therefore necessary, and this was provided in 1821 by Fresnel, who remarked that if the medium was assumed to possess a rigidity, or power of resisting attempts to distort its shape, it would be capable of transverse vibrations. It is by the possession of such a power that solid bodies are distinguished from fluids, which offer no resistance to distortion; and the idea of Young and Fresnel may therefore be expressed by the simple statement that *the aether behaves as an elastic solid*. This new hypothesis regarding the nature of the luminiferous medium provided the background of physics for the next half-century.

Some difficulties in the theory presented themselves immediately. If the aether has the qualities of a solid and permeates all space, how is it that we do not directly perceive it? And how are the planets in their orbital motions able to travel through it at immense speeds without encountering any perceptible resistance? A conjectural answer to this was made by Sir George Stokes, who remarked that such substances as pitch and shoemaker's wax, though so rigid as to be capable of elastic vibration, are yet sufficiently plastic to permit other bodies to pass slowly through them.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

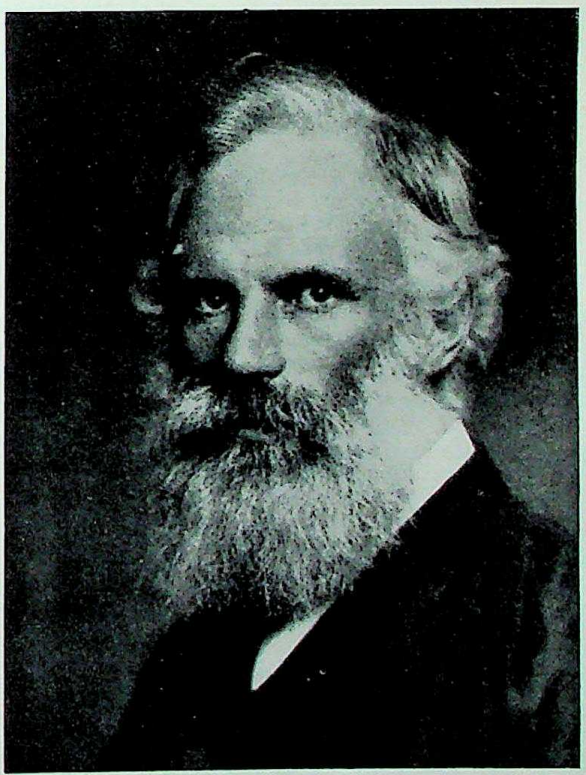


William Thomson (Lord Kelvin)

The aether, he suggested, might have this combination of qualities in an extreme degree, behaving like an elastic solid for vibrations as rapid as those of light, but yielding like a fluid to the much slower progressive motions of the planets.

Another difficulty is that while elastic solids provide the transverse waves which are necessary for the representation of light, they also admit of longitudinal waves; and it seemed impossible to keep the two completely apart, for when a transverse wave is incident on an interface separating two media, it gives rise in general to reflected and refracted waves of both the transverse and the longitudinal types. However, if Stokes' idea is correct, some approach to an explanation is provided by the circumstance that the ratio of the velocity of propagation of longitudinal waves to that of transverse waves increases rapidly as the medium becomes softer and more plastic, so that in a Stokesian aether the former velocity might be infinite and the longitudinal waves unobservable.

In the forty years following the discovery of transversality, a great number of papers were written with the aim of harmonizing the observed properties of light with the theoretical behaviour of waves in elastic solids of various types. Many alternative possibilities were open, e.g. it might be assumed that the vibrations of the aether were executed either parallel to the plane of polarization of the light or at right-angles to it; and that the different refractive powers of different media were due either to differences in the inertia of the aether within the media or to differences in its elasticity, or to both these causes combined. Moreover, the longitudinal waves might be abolished either by supposing their velocity to be infinite or by supposing it to be zero. No combination of these assumptions proved completely satisfactory; but in 1839 MacCullagh of Dublin proposed a new type of elastic solid, in which the potential energy depended only on the *rotation* of the volume elements (in an ordinary elastic solid it depends on their change of size and shape). The properties of this aether corresponded exactly with the known behaviour of light. There was some reluctance to accept MacCullagh's scheme, on the ground that no body endowed with the qualities postulated was found in nature; and this objection was not removed until half a century afterwards, when William Thomson (Lord Kelvin) designed a model composed of spheres, bars, caps,



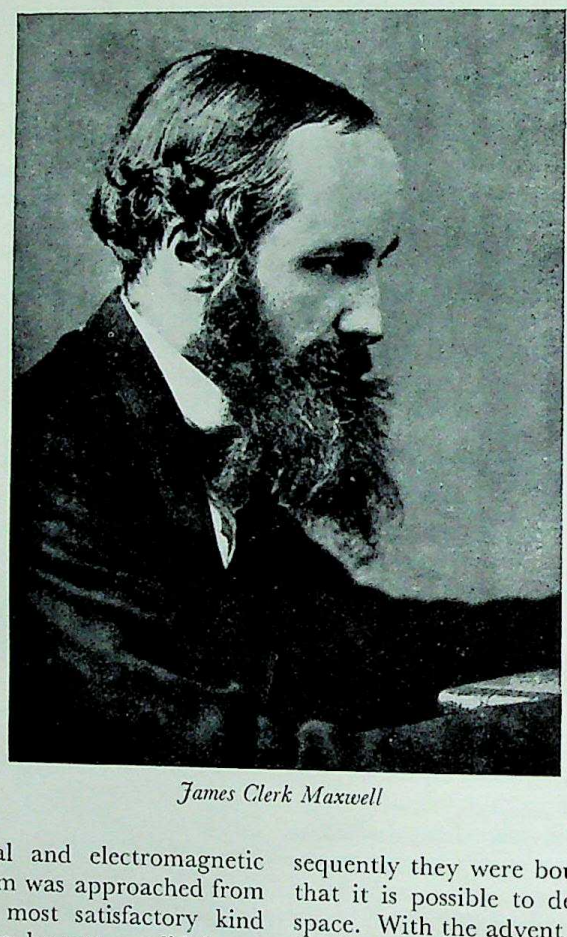
G. F. FitzGerald

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

and flywheels which possessed exactly the rotational elasticity of MacCullagh's elastic solid.

The development of the theory we have sketched, during the first half of the nineteenth century, was almost entirely directed towards the construction of an aether which should account for the propagation of light. But there are other physical effects which can be transmitted through a so-called vacuum; and as early as 1800 Young had remarked: 'whether the electric ether is to be considered the same with the luminous ether, if such a fluid exists, may perhaps at some future time be discovered by experiment.' Fifty years later, Faraday wrote: 'It is not at all unlikely that if there be an aether, it should have other uses than simply the conveyance of radiation.' In the second half of the century, the aim was to design a medium capable of accounting not only for light but for gravitation, electricity, and magnetism.



James Clerk Maxwell

Some attempts had been made independently to invent aethers suitable for the representation of gravitational and electromagnetic forces. When the problem was approached from this side, however, the most satisfactory kind of medium was found to be not a solid but a liquid. The Norse physicist C. A. Bjerknes studied the motion of a liquid in which is immersed a sphere capable of regular pulsation (change of volume), and showed that two such spheres, immersed in the same liquid and pulsating in unison, would, by the mediation of the liquid, exert on each other an attraction obeying the inverse square law which is characteristic both of gravitation and of electricity. A model due to William Thomson, showing how the forces between bar magnets can be imitated by actions propagated in a medium, also depends on a liquid aether.

The electromagnetic theory of Maxwell, which was promulgated in 1861–62, showed, in the words of its author, that 'light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena'; and from this time on, the primary aim of aether inventors was to represent the electromagnetic field. For this purpose they found it desirable to combine the qualities of the solid and liquid aethers, which was done in an ingenious way by postulating as the ultimate physical reality an incompressible liquid, but supposing it to be thickly populated with vortex-filaments, which, so to speak, reinforce it and confer on it a quasi-rigidity. A model of this type which was devised by W. Thomson and FitzGerald exhibited in a most remarkable way all the fundamental actions of classical physics.

The solid and liquid aethers of the nineteenth century had one feature which in the end proved fatal to them—namely that the phrase 'velocity relative to the aether' had a meaning, and consequently they were bound up with the doctrine that it is possible to define absolute velocity in space. With the advent of the theory of relativity in 1905, this doctrine was seen to be erroneous, and the search for a quasi-material aether came to an end. The curvature of space-time, which to some extent takes the place of an aether in the scheme of general relativity, belongs to a different order of ideas.

In any case, some modern philosophers would say that the physicists' notion, that an aether is necessary in order to account for phenomena which take place in a vacuum, is based on false metaphysics. A predicate need not have a subject: if undulations are taking place, we are not entitled to infer the existence of some *thing* that is performing them. But that is another story.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Book reviews

CHROMATOGRAPHY

Principles and Practice of Chromatography, *by L. Zechmeister and L. Cholnoky. Translated from the second and enlarged German edition by A. L. Bacharach and F. A. Robinson. Foreword by I. M. Heilbron. Pp. xv + 378. Chapman & Hall Limited, London.* 1943. 25*s. net.*

The pioneering experiment of Tswett in 1906 remained more or less neglected until 1931, when his adsorption columns were successfully employed by Kuhn and others in their work on polyene pigments. Since that time progress has been extremely rapid and an excellent account of the subject has been given in German by two well-known workers in this field, Zechmeister and Cholnoky. The translation by Bacharach and Robinson has been well done and will be particularly welcome to British scientific workers.

Chapter I deals with the scope of chromatographic analysis; this covers the testing of the homogeneity of a substance, establishing the possible identity of two substances, concentration from great dilutions, separation of mixtures and of some stereo-isomerides, purification, and the identification and control of commercial products. The essentials of the technique of the method are discussed in Chapter II: a good account is given of adsorption media, solvents, eluents, apparatus (including that for micro-chromatography), formation of column, development and extrusion. The chromatographic separation of colourless substances by the use of chemical transformation into coloured substances, by ultra-violet light, by indicators, and by colour reactions is also described. The remaining chapters are devoted to the successful application of the method to naturally occurring pigments (chlorophyll, haemin, porphyrins, bile-pigments, carotenoids, flavine, pterins and anthocyanins), to synthetic dyestuffs, to colourless and faintly coloured substances (including terpenes, polycyclic aromatic hydrocarbons, sterols and bile-acids, sapogenins, alkaloids, vitamins, hormones, and enzymes), to technology (tannin extracts, butter, drugs, and galenicals), and to inorganic chemistry (separation of cations and anions, and purification of inorganic substances).

The book is well provided with diagrams and photographs: a notable feature is the numerous clear graphical formulae of complex organic substances. A comprehensive bibliography to the summer of 1938 is incorporated; this has been extended by the translators to 1941.

The volume should make a particular appeal to organic chemists and biochemists, but doubtless many other scientists, including industrial chemists, will find much of interest in its pages.

A. I. VOGEL

COMPLEX POLYMERIC SUBSTANCES

High Polymers. A Series of Monographs on the Chemistry, Physics, and Technology of High Polymeric Substances, *edited by R. E. Burk, H. Mark, and G. S. Whitby. 4 vols. Pp. xix + 459; x + 345; xiii + 476; xviii + 690. Interscience Publishers Inc., New York; Imperia Book Company Limited, London.* 1940–42. $8.50; $6.50; $6.50; $11.00.

A perusal of the volumes under review might lead to the question: What is there that is not a high polymer?—for the term is no longer restricted to amorphous substances, often called colloidal, but to crystalline materials like the silicates. The general reason for the appearance of a comprehensive survey of high polymers is the significant advance which has been made in synthesizing high polymers, and in understanding the mechanism of that synthesis and the structure of the products resulting therefrom. The clarification of ideas has had its repercussions in elucidating the behaviour of many of the naturally occurring high polymers which had hitherto appeared to lie outside the systematic framework of chemistry. Some of the rigid views held about the nature of molecules have had to be drastically reviewed in the light of that knowledge, but this has not led to the subject becoming any less exact than that of other branches of chemistry.

A tribute to a leader in this new branch of chemistry is paid by publishing the collected works of the late W. H. Carothers in the first volume. It is difficult to realize that so much was accomplished in these few years of intense activity. Physical chemistry is so bound up with advances in high polymers that the editors wisely decided to devote Volume 2 to the fundamentals required for a proper understanding of the subject. This logically leads to Volume 3, in which the detailed mechanism of synthesis is discussed. Here again a relevant review of chemical kinetics provides a firm background for the study of the remainder of the book. In Volume 4 we find the most comprehensive survey yet offered of polymers inorganic and organic, crystalline and amorphous, natural and synthetic. Such a survey cannot but impress the reader with the almost universal appearance of these substances in every branch of chemistry. The names of the authors are an adequate guarantee that a high level is reached in this invaluable work.

H. W. MELVILLE

AN INTRODUCTION TO IMMUNOLOGY

Fundamentals of Immunology, *by William C. Boyd. Pp. xiv + 446. Interscience Publishers Inc., New York; Imperia Book Company Limited, London.* 1943. $5.50 *net.*

This work is designed to serve as an introduction to immunology for chemists and biologists. The subject is presented in a simple literary style and with almost complete abandonment of the historical approach. The importance of chemistry for immunology receives prominence in systematic accounts of the conjugated antigens and the influence of constitution on serological specificity therein. Turning to subjects preponderantly biological, we find good accounts of antibody formation, anaphylaxis, immunity to bacteria and viruses, and the significance of serological methods for comparative zoology. As would be expected from the author's interests, the most authoritative section is that dealing with antigen–antibody reactions. Documentation throughout is excellent, and includes notice of the relevant papers of 1941–42, e.g. Pauling's claim to have produced antibody-like properties in proteins *in vitro*, and the discovery that *erythroblastosis foetalis* is frequently due to incompatibility in respect of the Rh antigen.

The development of immunology as an applied science has largely prevented its fundamentals from exerting their proper influence on biology as a whole. There is need, it follows, for interpretation of these conceptions and their synthesis with those from other disciplines. From this viewpoint the ideal text remains to be written, but Professor Boyd's book goes at least a part of the way as a modern exposition of the basic principles.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

ATOMISTICS AND THERMO-DYNAMICS

A Treatise on Physical Chemistry. *Edited by Hugh S. Taylor and Samuel Glasstone. Third Edition in Five Volumes. Volume I, Atomistics and Thermodynamics. Pp. vii + 679, with numerous diagrams. Macmillan & Co. Limited, London.* 42*s. net.*

This co-operative effort of a group of physical chemists, in which the subject of physical chemistry is developed from comparatively simple beginnings up to the furthest outposts of knowledge, will be welcomed alike by research workers and teachers of physical chemistry. There are chapters on the atomic concept of matter, the quantum theory of atomic spectra and atomic structure, the first and second laws of thermodynamics, and the third law of thermodynamics and statistical mechanics, in which the old and the new are embodied in a coherent doctrine. In each generation, a new synthesis is required of the borderland between physics and chemistry, which is achieved in part by physico-chemical researches and in part by comprehensive treatises. The thoughtful sections on the third law of thermodynamics and on the quantum theory provide good examples of the operation of the latter process. In the main, we are dependent on the initiative of individuals for the co-ordination of knowledge and we are grateful to the editors of the present volume.

W. E. GARNER

NUMERICAL BIOLOGY

Statistical Analysis in Biology, *by K. Mather. Pp.* 247, *with* 9 *diagrams. Methuen & Co. Limited, London.* 1943. 16*s. net.*

Dr Mather is a member of the halieutic[1] school of statistical biologists, and has applied Professor Fisher's methods to a variety of problems, mainly genetical. His book will be of real value to the increasing number of biologists who are, often reluctantly, being forced to use statistical methods. The examples are in many cases more fully worked out than those in Professor Fisher's own books, though no attempt is made to prove the validity of the methods used. However, their interrelations are clearly set out.

Among the subjects treated are tests of significance, the analysis of variance, the planning of experiments, correlation and regression, tests for homogeneity, and the estimation of parameters. Among the subjects not considered in any detail are the biological assay of drugs, vitamins, and the like, life tables, the estimation of population numbers by trapping and release, the laws of growth, and the theories of population change which are gradually concretizing and modifying the Darwinian theory of natural selection. These could hardly have been dealt with in a book of this size. But they are all important. In fact, a book which dealt even cursorily with all the fundamental applications of statistics to biology would be very large. Let us hope that such a book will be written as soon as more paper is available. Meanwhile Dr Mather's book will undoubtedly prove useful in many biological laboratories.

J. B. S. HALDANE

[1] From ἁλιευτης, a fisher.

THE TESTING OF FUELS

Fuel Testing, *by G. W. Himus. Pp. xvi* + 288. *Leonard Hill Limited, London.* 1942. 21*s. net.*

The conditions brought about by the war have emphasized the need for economy of fuel and have also restricted the availability of various types and grades of fuel. In these circumstances the appearance of a second edition of the book under review is most opportune. The same general plan has been followed as in the case of the first edition published in March 1932, and the methods for sampling and for carrying out the various physical and analytical determinations are based upon the recommendations of the British Standards Institution, the Fuel Research Board, and the Institute of Petroleum. It may be mentioned here that while specifications, such as those referred to above, are drawn up, quite properly, with a minimum of discussion on general principles, Dr Himus has successfully dealt with the principles in sufficient detail while still adhering to the spirit of the specifications.

In the first edition there was a chapter on the classification of coal. This has been omitted in the present one, but there is an important addition consisting of an excellent chapter on combustion calculations which should be of particular use at the present time.

The text is illustrated by fifty-nine diagrams, including four plates, and the book should be of considerable assistance to those concerned with fuel problems.

ARTHUR MARSDEN

CONTROL OF INSECT PESTS

The Biological Control of Insects, *by Hugh Nicol. Pp.* 174. *A Pelican Book, published by Penguin Books Limited, London and New York.* 1943. 9*d. net.*

The theory and practice of the biological control of insect pests forms an attractive chapter in applied science. For the general reader accounts of what has been done, and is still being done, in this field are very few outside technical publications. Dr Nicol's book is the story of a man's attempts, by means of living organisms, to create a state of biological equilibrium between plants and their environment. He has brought together much of the available information on the subject and woven it into a very readable book. Written in a style free from undue technicality, it can be commended as presenting a reliable picture of the whole subject.

A MODERN UTOPIA

An Unknown Land, *by Viscount Samuel. Pp.* 221. *George Allen & Unwin Limited, London.* 1942. 12*s.* 6*d. net.*

Viscount Samuel's book might be called 'The New Atlantis Revisited,' for it is a thought-provoking and invigorating description of the present condition of Francis Bacon's Utopian island of Bensalem, hidden away in the remote Southern Pacific. Here we find a highly cultured people who have eliminated, *inter alia*, taxation, currency, banks, and bills; charges for water, electricity, and other services and commodities; police, judges, and lawyers; disease, poverty, and wealth; slums and the struggle for existence; weeds and hedging; handkerchiefs, keys, and watches; tobacco, coal, oil, and rubber; and—perhaps most significant of all—foreign relations and war. The Bensals are indeed the world's most complete and successful isolationists. Their economic system, based upon free and unlimited sub-atomic energy, is co-operative and not competitive; but they find an outlet for the spirit of emulation in cultural activities. The practical details of the life of this ideal community, as well as their conceptions of philosophy, science, and religion, are worked out in surprising detail. Clearly a product of much inquiry and original reflection, this book should be a powerful stimulant to planners of a 'brave new world' in this epoch of rapid change.

J.R.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME II OCTOBER 1943 NUMBER 8

Sound

At a time when atomic physics captivates both professional and lay attention, it is opportune to note that in no branch of science has technical development in recent years been more remarkable than in sound. Thirty years ago sound, which earlier, under the influence of British scientists like Tyndall and Rayleigh, had been a popular study, was a neglected subject in the universities, and one which, in spite of the gramophone and the telephone, was not very much cultivated in commercial laboratories. Today, largely owing to the importance of the cinematograph and broadcasting industries, the study of mechanical vibrations produced by and producing electrical and optical effects, and the investigation of the effects of air-borne vibrations upon the human ear in a great variety of circumstances, have created a body of ordered knowledge, comprehended under the general title of 'sound,' which forms a noteworthy part of modern physics.

The reproduction and recording of sound are now governed by a precision of calculation and design which has been made possible by the introduction of mathematical methods originally worked out for electrical circuits carrying alternating currents. An essential feature of any apparatus of the speaking or receiving type is a diaphragm or similar membrane whose vibrations are governed—forced, to use the technical term—by quickly varying forces, and it is of prime importance that the diaphragm shall follow faithfully. The forced vibrations of a mechanical system made up of diaphragms loaded in various ways are now investigated in terms of properties borrowed, in virtue of a close analogy, from the electrical circuit, so that conceptions such as impedance, long familiar in electrical calculations, are freely utilized in the case of mechanical vibrations. In place of tentative empirical methods we have accurate calculation which enables the performance of a given arrangement to be predicted, and results in a perfection of achievement exemplified by the very high fidelity of sound reproduction that characterizes the best modern instruments. The technique of modern alternating current circuits is, of course, applied directly to the problem, as well as indirectly, through mathematical analogy. With two 'speakers,' one for high frequencies and one for low frequencies, and with suitable electrical circuits to ensure that each one deals only with the range for which it is adapted, astonishing results can be obtained. This is but one aspect of the new methods comprehended in the term 'electro-acoustics,' which not only indicates the combination of electrical and mechanical apparatus but also the methods by which masses, restoring forces represented by springs and the like, and mechanical resistance find their analogies in electrical terms.

An extension of these studies is represented by new methods of reproducing and recording, unknown thirty years ago. The use of a light-beam of rapidly changing intensity to produce, by the agency of a photo-electric cell, first of all electrical variations and ultimately sound, is essential to the speaking film. The sound-track is usually made by causing the sound to regulate the strength of a light-beam which acts on a photographic film. The means by which the regulation is effected are manifold, complicated, and curious. There is, however, a method of recording the sound as a light-track which requires no photographic development. In this, a device cuts away mechanically the thin opaque covering on a transparent film. The principle is simple, the achievement excellent; but the elaboration of the process was a complicated piece of work requiring the highest skill in the new scientific technique. The imprinting on a running steel strip, or on a running band impregnated with a magnetic powder, of residual magnetism varying in degree with the sound vibrations is another popular method of

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

recording and reproducing, exemplifying the invocation of still another branch of physics.

A further field which is now the subject of precise investigation instead of hazardous trial is architectural acoustics. No architect would (or should) now design a hall for speech or music without specialized scientific advice. The prevention of, and protection from, noise is another allied sphere in which advances have recently been made, and one of profound importance, for the appreciation of silence is not the least significant cultural effect of our state-aided services.

The whole subject of vibrations of frequencies much too high to be audible, the so-called supersonics (or ultrasonics, as some prefer to call them), is another recent development. That the application of electrical charges to opposite faces of a quartz slab suitably cut leads to stresses in the slab follows from Curie's discovery of piezo-electricity. This makes it possible, by applying a rapidly varying electrical force to a crystal, to maintain vibrations of a frequency of several hundred thousand a second, the frequency being that proper to the longitudinal vibrations of the extremely short bar constituted by the crystal slab. This steady production of extremely high mechanical frequencies has had important results in pure science, as exemplified by the discovery of abnormal absorptions and velocities of sound in certain gases, traceable to certain types of molecular vibrations, and by the discovery of effects on small living organisms. It has also had a variety of practical applications. The vibrations of a quartz ring, piezo-electrically maintained, have been used to control a clock which varies by not more than a couple of thousandths of a second per day. The detection of cracks in solids and of the setting points of cements represents quite another utility.

Not the least remarkable of technical advances is, perhaps, the invention of electrical musical instruments, in which the player governs directly, by one means or another, electrical circuits producing electrical oscillations which are finally made audible by being fed into a loudspeaker. The tone producer may, for instance, be a revolving wheel with teeth that move past an electrical pick-up and so excite a pure tone, which can be blended with other pure tones, harmonics, at the discretion of the player. With an instrument based on such principles the player can produce not only the effect of the stops of the classical organ, but can manufacture others for himself. He can produce any frequency, any loudness, maintain the note for as long as he likes, and build up any quality. Many types of electrical organ and electrical piano have been produced. The great virtuosos on such instruments are still to be formed and it is interesting to await the possible artistic developments.

Though many of the striking recent developments in sound are due to the technical laboratories of great industrial concerns, the basis of all the progress is to be found in the discoveries made by workers in pure science. To some of these discoveries, in the mathematical study of vibrations and in supersonics, we hope to devote articles in forthcoming issues of ENDEAVOUR.

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

THE PLACE OF SCIENTISTS IN THE COMMUNITY

From Sir Robert Pickard, *Chairman, Joint Council of Professional Scientists;* Alex. Findlay, *President, the Royal Institute of Chemistry; and* Sir Lawrence Bragg, *President, the Institute of Physics.*

Although, in the British Dominions no less than in Britain itself, great advances in scientific research and in technology have been made since the war of 1914–18, it is perhaps still doubtful whether our peoples have, even yet, acquired that appreciation of science and understanding of its potentialities which are the only safeguard of our industrial future. While the important part which scientific and technological research has played in our war effort may find a widespread recognition, it is not less necessary that scientists should make it clear that if our countries are to be able to

(*Continued on page 141*)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The electron microscope

SIR GEORGE THOMSON

So far, atoms have been abstract conceptions deduced from experiment. Within the next few years we may be able to say of them 'seeing is believing,' for the electron microscope—here described by Sir George Thomson—is likely to render them visible. The electron microscope has already made possible noteworthy advances in pure science and excites hopes of providing a tool of the highest importance in medical research.

The last few years have seen an important development in the centuries-old art of observing the very minute. This has come about in a curious way. The visual microscope, from the ordinary hand lens to the most powerful instrument used in bacteriology or metallurgy, acts on the following principle: light from the object is bent by means of lenses of glass or other transparent material in such a way that when it enters the eye it is spread over a much larger area of the retina than it would have been if the object had been viewed in the ordinary way at the least distance from the eye at which clear vision is possible. The light from each point of the object is focused on to one element of the retina which perceives it. The collection of illuminated elements forms an *image* which causes vision of the object, and the apparent size of the object varies with the size of the image. Exactly the same thing happens in a photographic microscope, except that here the final image is on the photographic plate which acts as a kind of artificial retina, fixing the image so that it can be studied at leisure. Now though the eye is sensitive to light only, there are other forms of energy which can affect a photographic plate and, provided they can form an image, might be used in a photographic microscope. In fact, ultra-violet light, which differs from visible light only in its shorter wave-length, has long been so used for a reason which will appear shortly. But the possibilities do not stop here; other sorts of radiation will serve. The requirements are these: firstly the radiation must form 'rays' and not spread more than a small amount, otherwise the effects from different parts of the object will get inextricably mixed and it will be impossible to see its shape; secondly, it must be possible to control the rays so that those from one point of the object come together at or near one point of the image. The first requirement rules out radio waves or sound, the second would make it impracticable to use X-rays. Electrons, however, fulfil both requirements, and the purpose of this article is to show how they are being used in place of light in microscopes of unprecedented power.

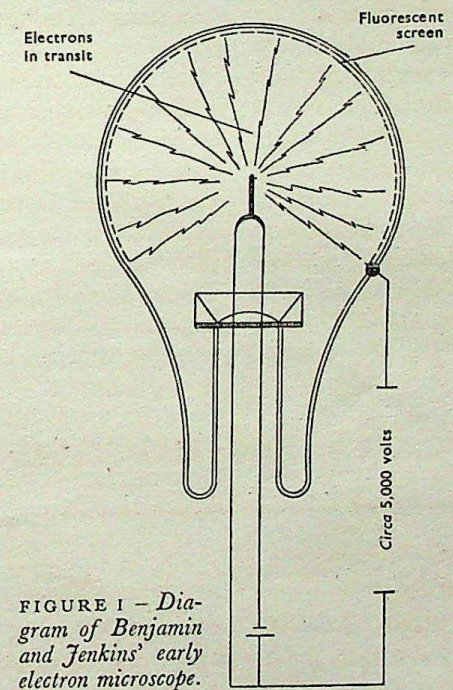


FIGURE 1 – *Diagram of Benjamin and Jenkins' early electron microscope.*

ELECTRONS

When an electric discharge passes through a gas at low pressure, rays leave the cathode or negative pole which can affect a photographic plate if they strike it, or can light up a fluorescent screen of (for example) powdered willemite placed in their way. These cathode rays are *electrons* and can be deflected by electric or magnetic fields. Some of the rays can be selected by letting them pass through a hole in a diaphragm inside the low-pressure region, and a fine beam can thus be formed. The cathode ray oscilloscope, an instrument which has found a thousand uses in the study of radio, makes use of the deflection of such a beam and is in fact an adaptation of the apparatus originally used by

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Sir J. J. Thomson in his proof of the nature of cathode rays.

Electrons can, of course, be produced in other ways: they are emitted from a heated filament as in the ordinary radio valve, and can even be pulled directly out of a cold metal by very intense electric fields. However produced, they fulfil our requirements of going in approximately straight lines when not acted on by forces, and of being controllable by electric and magnetic fields.

A PRIMITIVE ELECTRON MICROSCOPE

The simplest form of electron microscope, though not the first to be discovered, is illustrated in figure 1, which shows the set-up used by the English scientists Benjamin[1] and Jenkins. Here the point of a wire is made to emit electrons which are accelerated by a radial electric field till they strike the surface of a bulb covered with fluorescent material. If, for example, one side of the point emits more electrons than the other, the corresponding side of the bulb will glow more brightly. In fact, the result is much better than this. Each small region on the point produces its corresponding patch of fluorescence, so that the surface of the bulb reproduces the emitting power of the different parts of the point of the wire; but since the surface of the bulb is enormously larger than that of the point, there is an enormous magnification. If the point were a small hemisphere the magnification would be the ratio of the radius of the bulb to that of the hemisphere.

The points used were of the order of $\frac{1}{100000}$ in. in radius, and the magnification was about 200,000. As is well known, a sharp point greatly increases the strength of an electric field, and with a point as fine as this a quite moderate voltage—under 10,000—is enough to pull electrons out of the wire by brute force, even though the wire is not nearly hot enough to emit them in the ordinary way. The effective part of the point turns out to be a single crystal of the metal of the wire, which was etched before use. Figures 6 and 8, kindly supplied by Dr Jenkins, show the kind of results which this instrument gives. The black patches show that there are certain regions which emit no electrons, and a study of their distribution in the light of the known crystal structure of the wire shows that they correspond to certain special crystal faces. It is probable that most of the emission comes from the edges where the faces join, and where the electric force is specially intense; but there is also a difference between crystallographically different faces. It also seems likely that, when the wire is heated, the mechanical forces on the surface due to the electric field are enough to pull out the edges between the faces into sharp *arêtes* even below the softening point of the metal, thus still further enhancing the concentration of field and intensifying the emission from the edges.

It is well known that the emitting powers of metals such as tungsten are much increased by a layer, only one atom thick, of the electropositive metals such as barium and thorium. This property is used to make 'dull-emitter' radio valves. Benjamin and Jenkins were able to study these changes by depositing small amounts of barium or thorium on the points of their wires and observing the changes in the fluorescent patterns so caused. Any part of the point which gets covered by the barium or thorium will emit more, and an increase in brightness will be seen on the part of the bulb corresponding to it. They were able to watch the foreign atoms migrating from the side of the point on which they were first deposited. The new atoms favour certain faces and edges of the crystal and avoid others. Surely it is one of the most remarkable achievements of experimental science that we should be able to follow in this way the movements and preferences of a few thousand atoms!

ELECTRIC LENSES

But though a most beautiful experiment, the uses of this device as a microscope are far too severely limited by its geometry and by the requirement that the surface shall itself emit electrons. The first restriction is lessened in the (earlier) apparatus of Brüche and Johannson. By passing a beam of electrons through a series of holes of varying size in two or three parallel screens maintained at carefully chosen electrical potentials, so that the electric forces round the edges of the holes pull the electrons from their paths, it is possible to make a beam which originally diverged from one point come together again and be focused on a photographic plate or fluorescent screen. The electrical field of the screens thus imitates the action of a convergent lens. In this way a magnified image of a small flat surface parallel to the screen can be formed and the electron emission from it studied. Many interesting results have been obtained. For example, it is known that the thorium atoms on a dull-emitter filament diffuse through the

[1]Dr Benjamin was unfortunately killed in an aeroplane accident while on Government service.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

tungsten to replace the losses by evaporation from the surface. It used to be thought that the atoms found their way along the interfaces separating the small crystals in the tungsten wire, but it now appears that they go right through the solid, arriving at the surface in small patches unrelated in position to the crystal boundaries.

Most of the experiments of this kind have been done with relatively small magnifications of the order of 100. In the form in which we have described it, this instrument is limited to the study of surfaces which can emit electrons, i.e., in practice, metals. It is believed, however, that the Allgemeine Elektrizitäts Gesellschaft is developing an instrument to use electrostatic lenses with high magnification and an independent electron source, and similar work is in progress at the General Electric Company's laboratories at Schenectady, but it is doubtful if this kind of instrument will have any important advantages over the types developed here and in America, and now to be described.

MAGNETIC LENSES

It has been common knowledge for a long time that a beam of electrons travelling along the axis of a long cylinder, round which a wire is wound in a spiral, is kept together by the magnetic field produced when a current flows in the wire, the field acting as a rather peculiar convergent lens but without magnification. It has more recently been found by Knoll and Ruska that a short coil also can be effective, and indeed is more closely analogous in its action to that of a glass lens on light, being able to give a magnified image. Thus a magnetically controlled electron microscope becomes possible, and has certain practical advantages over the electric type.

RESOLVING POWER AND THE LIMITS OF USEFUL MAGNIFICATIONS

Before entering on the details of these instruments it is worth while considering what determines the effective limits of a microscope of any kind. Let us suppose, to make the question definite, that we are examining a specimen (such as that in figure 7) which has a number of small slits or spots. We want to see the spots singly and not just as a smudge. That is to say the light (or electrons) from each spot must be separated from the others, and brought to a separate place on the retina of the eye or the photographic plate without confusion with the light from any other spot. This is called *resolution*, and the resolving power of a microscope is its most important property. In a compound microscope the *magnification* is by stages, each stage viewing the image formed by the one before; but magnification without adequate resolving power is as futile as to enlarge a fuzzy photograph in the hope of seeing more detail. The eye can distinguish spots about $\frac{1}{250}$ in. apart (0·1 mm.), and if the finest detail we want to see is magnified up to this scale we have done the job, though to save straining the eyes it may be desirable to magnify by a small further factor, say 5. Now the magnification might in theory be repeated in as many stages as we like, and there would seem to be no definite limit to the fineness of detail which could be magnified up to $\frac{1}{250}$ in. and so made visible. But here resolving power comes in. If at any stage the rays from two spots get hopelessly mixed, nothing we can do afterwards will unmix them. The individuality of the spots is lost and they are indistinguishable from one larger spot. Clearly, resolution is hardest when the spots are closest, so it is the first lens, which looks at them before they are magnified, which is most likely to fail in this respect.

As is well known, light is a form of wave-motion, and this fact governs the least distance apart at which spots can be distinguished. If one drops a stone into a calm pond, the place it hits will become the centre of expanding circular ripples. An intelligent water-beetle on the surface could tell the direction of the stone from the way the waves struck him. If two stones were dropped at the same time some considerable distance apart he would experience a rather irregular motion, which would be like that of a cross-sea, but which he could perceive was due to two separate sets of waves coming from different directions (figure 2). If, however, the two stones strike closer together than about the distance between the trough and crest of a wave, their two wave-systems will fuse and our water-beetle, however intelligent, will only think that one rather large stone has dropped (figure 3). This is an instance of a general rule for all kinds of wave-motion, which says that the least distance between two spots which allows them to be seen separately is about half a wave-length. For visible light this is about 0·00025 mm. Now $400 \times 0{\cdot}00025 = 0{\cdot}1$ mm., the least visible distance. Hence a magnification of 400 will suffice to make visible the least distance that can be resolved. It

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

may be worth going to × 1,000 or even × 2,000 to make the picture easier to read, but the extra magnification is wasted in the sense that nothing real can be seen which could not with care have been seen without it. Certainly any further magnification is merely misleading. However, we may use ultra-violet light and liquid immersion, both of which shorten the wave-length at the object, which is what matters. In these ways one can push the limit down to about 0·0001 mm. or 0·1 μ to use a unit common in microscopy, and magnifications up to about × 5,000 are useful in favourable circumstances.

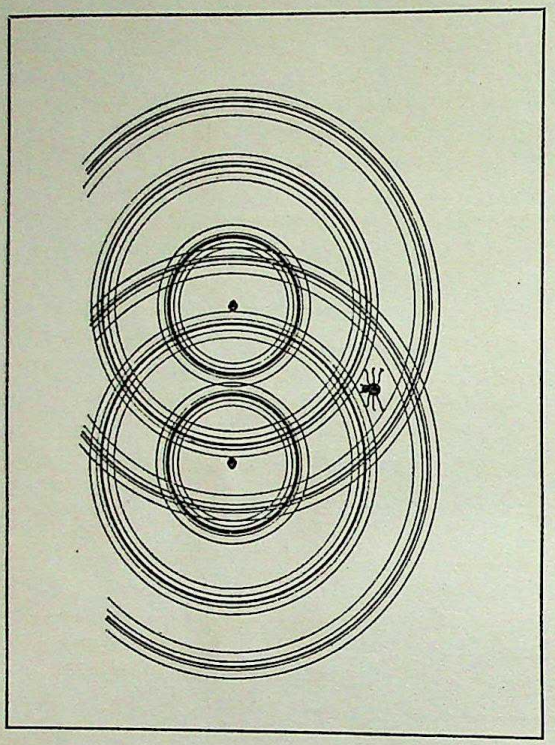


FIGURE 2

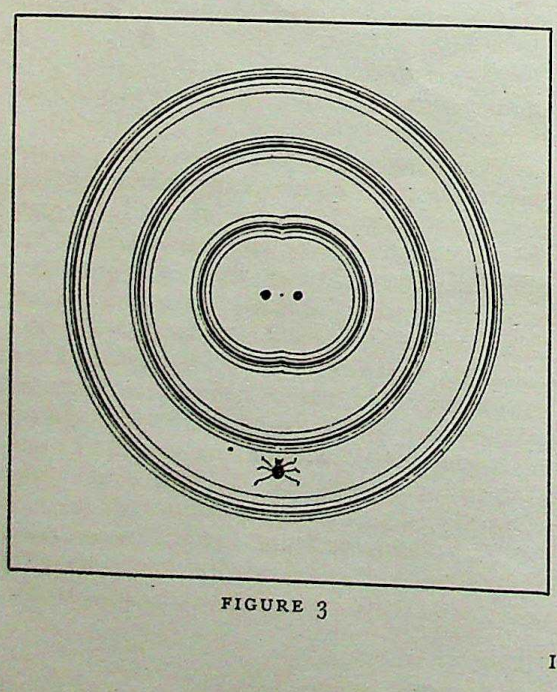


FIGURE 3

ELECTRON WAVES

Now how do electrons help here? Until fifteen years ago the answer would have been that if the electrons could be suitably handled there would be no lower limit, at least down to atomic sizes, because the electrons were thought of as particles much smaller than atoms. We now know that all particles, and in particular electrons, have a dual character, partly particle and partly wave. Without entering into the very difficult ideas involved it is enough to say here that, as far as resolution is concerned, electrons act like waves whose wave-length depends on their speed, the fastest electrons having the shortest waves. Slow electrons with a speed such as they would get by being accelerated from rest by a potential of a quarter of a volt, have a wave-length of about two millionths of a millimetre. Such might be the electrons at the moment of emission from a hot filament. Cathode rays with energy even of 15,000 volts have the truly minute wave-length of a one hundred millionth of a millimetre. These wave-lengths are much less than those of any usable ultra-violet light, are indeed no larger than those of X-rays, and allow a great increase in resolving power and useful magnification.

Actually things are not quite as favourable for the electron microscope as a crude comparison of wave-lengths indicates. The full resolving power can be achieved only if the lens can gather radiation coming from the object over a complete hemisphere. This is an unattainable ideal anyhow, but the best microscope objectives come fairly near it and take in a very wide cone of rays from each point of the object. With the electron microscope, at any rate with lenses of the existing types, it seems that what in an ordinary lens is called spherical aberration, which means a failure to form a perfect image for geometrical reasons, makes it necessary to use only a narrow cone of rays. This may give a factor of 100 or more against the electron microscope, but even so its theoretical resolving power with 15,000 volt electrons is about one millionth

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

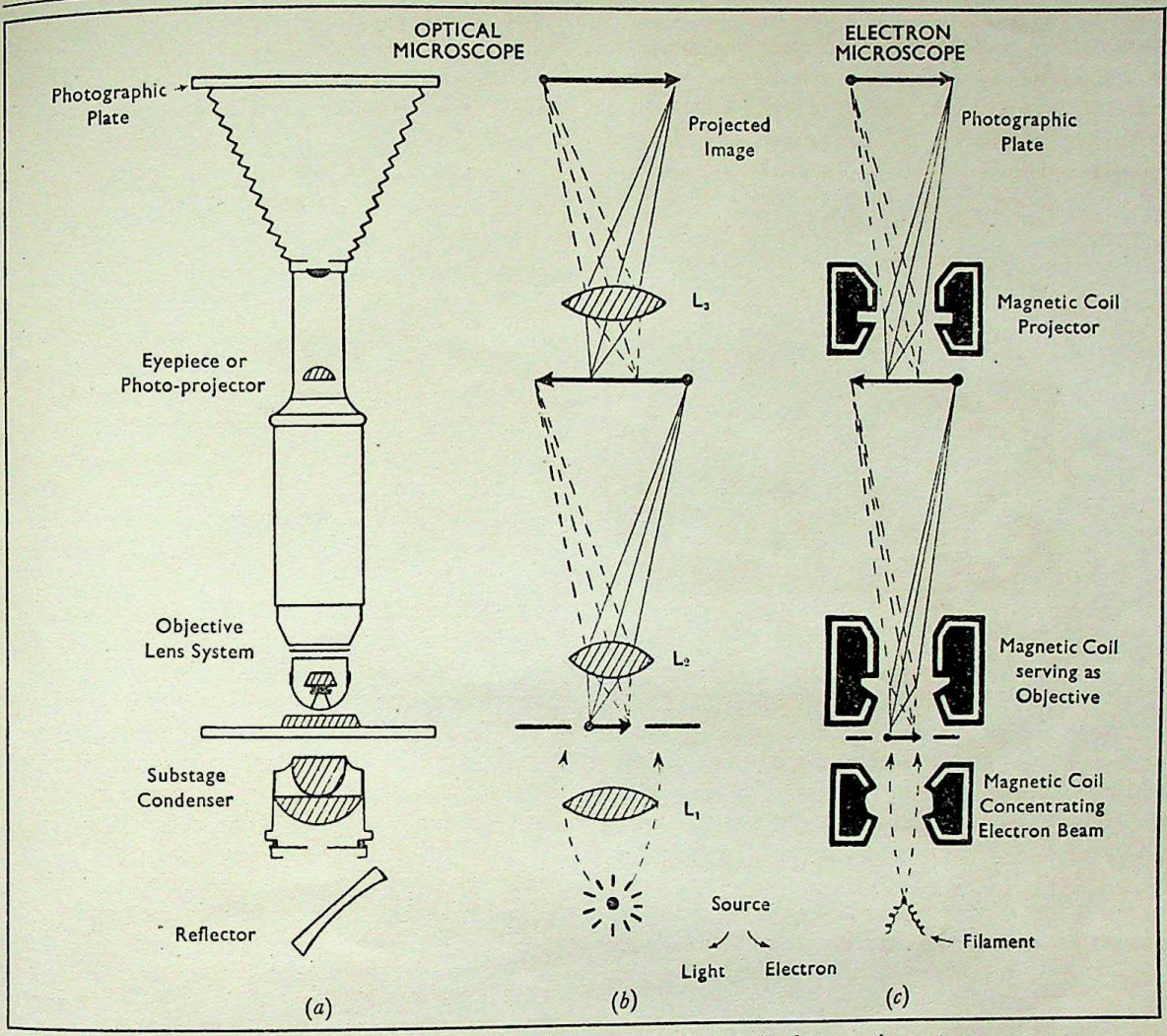


FIGURE 4 — *Comparison of light microscope and magnetic electron microscope.*

of a millimetre, or a hundred times better than the best obtainable with any probable use of ultra-violet light.

MAGNETIC ELECTRON MICROSCOPES

Instruments making use of these ideas to give very high resolving powers and useful magnifications have been developed in Belgium by Marton, in Great Britain at the Imperial College[1] and the National Physical Laboratory[2] with the aid of Metropolitan-Vickers, and in Canada and the United States. One of the most recent is that made by the R.C.A. Manufacturing Company, New Jersey, which incorporates a number of features developed by Professor E. F. Burton and his co-workers of Toronto University and is illustrated in figure 9.

The Toronto instrument, which resembles the above in its main features, is fairly typical of the newer practices. It stands about 5 ft. high and is exhausted to a very good vacuum by powerful pumps. The electrons are generated in a hot cathode and accelerated to about 45,000 volts. The electrons pass through the specimens, which have to be very thin and are usually mounted either on fine wire gauze or on a disc with a small hole in it. Three magnetic lenses are used, corresponding exactly to the condenser, objective, and eyepiece respectively of an ordinary microscope. How they are arranged is shown in figure 4, which shows each part of the electron microscope compared with the corresponding part of the light microscope,

[1]Professor Martin and others.
[2]Dr Preston and others in the Metallurgy Department.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

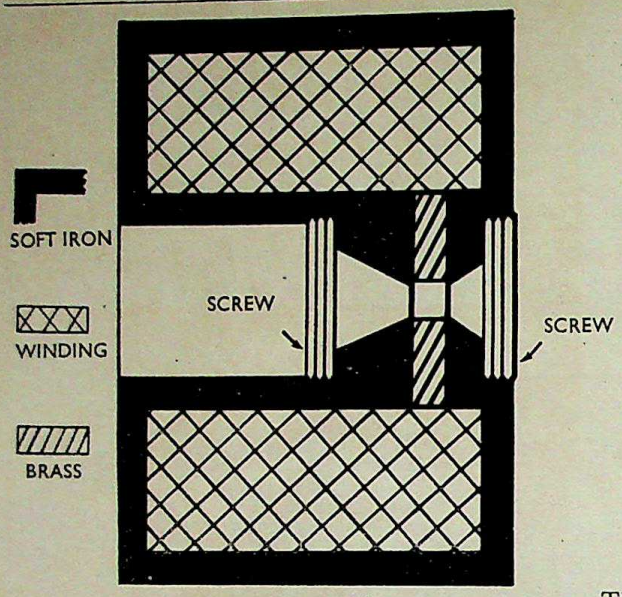


FIGURE 5 — *Modern magnetic lens as used in magnetic electron microscope.*

and how the paths of the electron imitate the rays of light. In the figure the electron microscope is shown with its source of illumination below and the final image at the top, for comparison with its optical analogue. In practice, the instrument is so tall that it is more convenient to have the source with its high potential up above out of the way, so that the figure should be reversed for comparison with the picture in figure 9.

The first-stage magnified image formed by the objective can, if desired, be thrown on to a fluorescent screen for adjustments to be made. The final image can also be viewed in the same way on a second screen, or the fluorescent screen can be removed and the electrons allowed to strike a photographic plate, where they produce a latent image which can be developed in the ordinary way.

The type of 'lens' now generally used is shown in figure 5. It is a short hollow cylindrical coil of wire, carrying a current and entirely enclosed in an iron sheath, except for a narrow brass ring on the inner surface. This brass ring interrupts the lines of magnetic force which tend to run in the iron, and forces them into the open. The thickening of the iron on each side of the brass narrows the hole here and increases the concentration of magnetic forces near this part of the axial line. Such a lens may have a useful focal length of about 5 mm.

With instruments such as these, magnifications of × 20,000, × 40,000, and × 60,000 are readily obtainable, and even one of 150,000 diameters is possible. What is, as we have seen, more important is the resolving power. The best estimates of this show that a resolving power of $\frac{1}{100000}$ mm. is readily obtained in practice, while under the best conditions results two or three times as good are possible, which is not too far below that predicted by theory. Even the lower value is ten times as good as in the best ultra-violet microscope. The images obtained are very sharp, and it is a good plan to use a fine-grained photographic plate and magnify the results visually about ten-fold. The accompanying illustrations (figures 10–16) show a few of the results obtained on very varying kinds of specimens[1].

The R.C.A. instrument has a device to allow the specimen to be changed without letting down the vacuum in the whole instrument. It is most important that the lenses and the specimen should be adjustable with respect to one another, for no accuracy of manufacture can prevent slight asymmetries, and these become enormously magnified. To allow this to be done the instrument is made in six sections—one above the other. The top and bottom of each section are ground perfectly flat, and the joints made airtight with grease. The sections can be pushed slowly over each other by adjusting screws and accurately alined without spoiling the vacuum. It is also important to ensure that the inside of the camera is kept very clean and free from grease, which might become electrically charged and deflect the electron beam.

It is essential to maintain the voltage accelerating the electron at an extremely constant value. In fact, the 45,000 volts of the Toronto instrument are not allowed to vary by more than a single volt. To do this, of course, requires an elaborate electric installation, and use is made of radio technique. The reason for this extreme constancy is that electrons of different speeds are bent differently by the magnetic lenses, just as light of different colours is bent differently by

[1]Figures 13, 15, and 16 were taken with the Toronto instrument and are reproduced from *The Electron Microscope* (Burton and Kohl) by kind permission of Reinhold Publishing Corporation. Figures 10, 11, 12, and 14 were taken in the Metallurgy Department of the National Physical Laboratory and are reproduced by kind permission of the Director. The instrument used is indicated on each.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

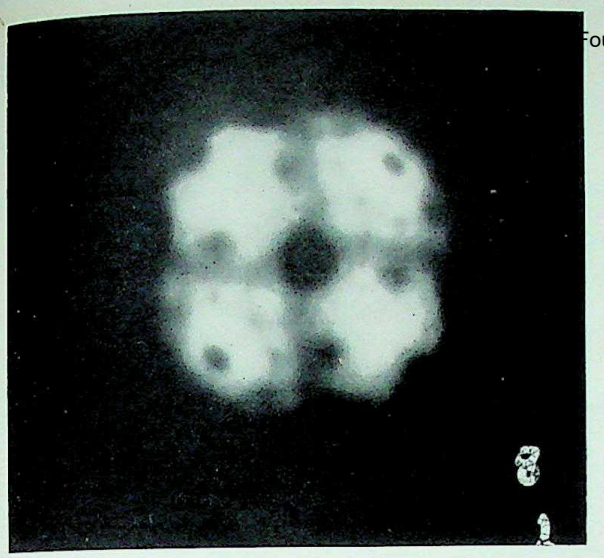


FIGURE 6 – *Emission from a molybdenum point, partially smoothed by heating for a short time to a high temperature. The black spots correspond to crystal faces.* (*From Dr. Jenkins.*)

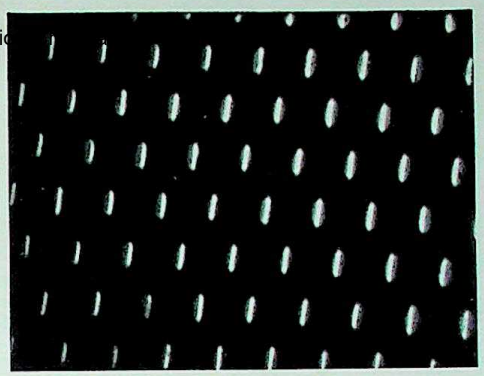


FIGURE 7 – Diatom: Pleurosigma angulatum. *The shell of this small plant is pierced by a regular array of small holes. The structure is just beyond the resolving power of an optical microscope.* (×14,000)

(*Taken with R.C.A. instrument at the National Physical Laboratory.*)

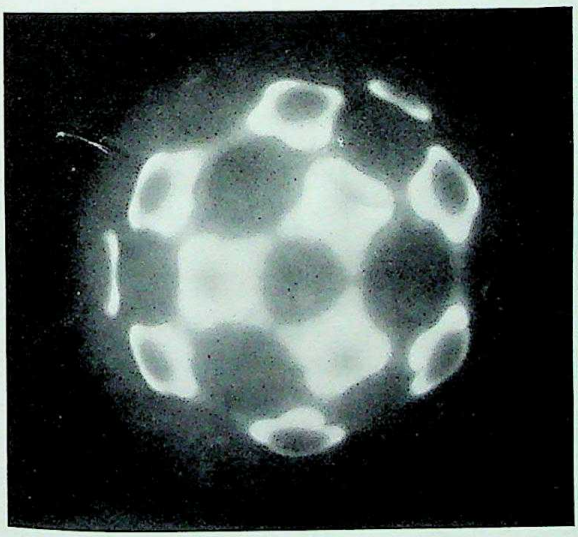


FIGURE 8 – *Emission from a nickel point heated to* 920° *C. The black regions correspond to crystal faces, the regions of emission to edges.* (*From Jenkins.*)

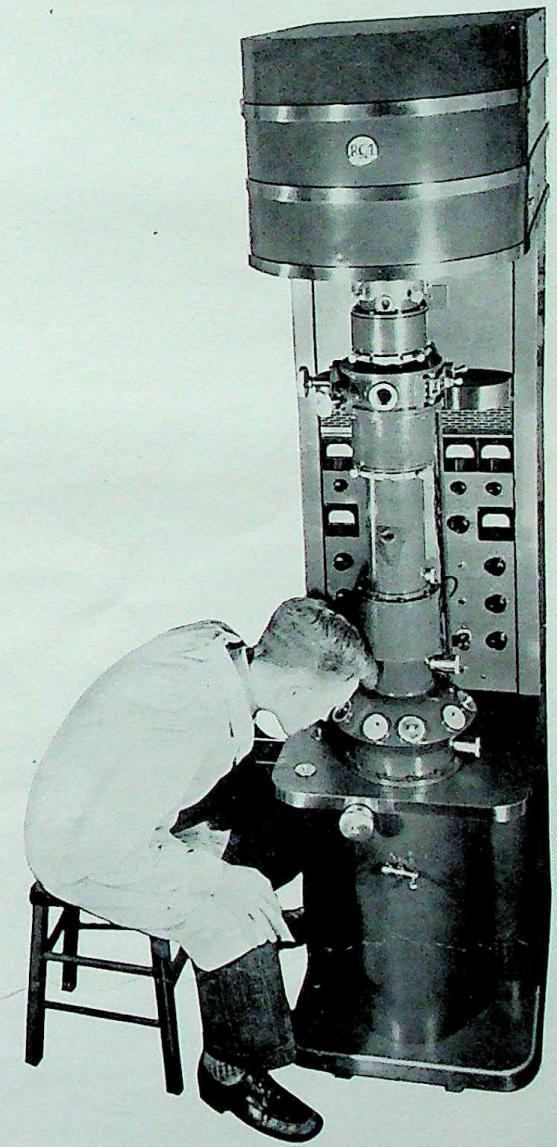


FIGURE 9 (*right*) – *An R.C.A. magnetic electron microscope.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

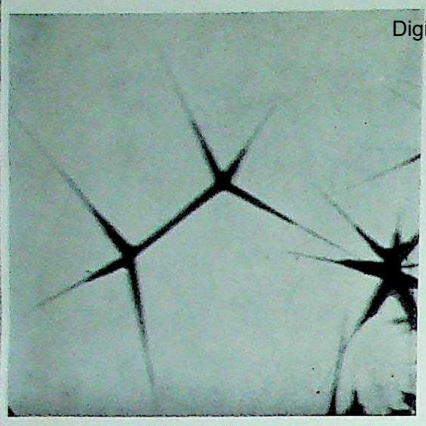


FIGURE 10 – Zinc oxide smoke, *produced by burning metallic zinc: consists of long needle-like crystals of zinc oxide.* (×ca. 7,000)
(Taken with Metro-Vic instrument at the National Physical Laboratory.)

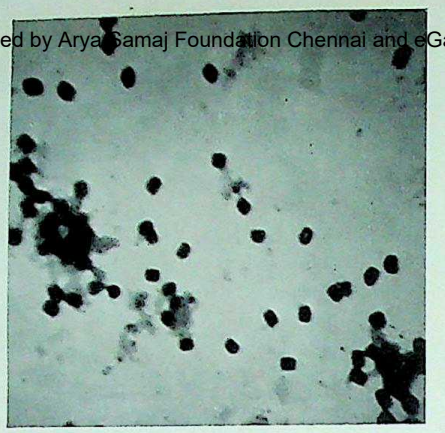


FIGURE 11 – Vaccinia. *The small oblong bodies are the active agent which produces immunity from small-pox.* (×10,000)
(Taken with Metro-Vic instrument at the National Physical Laboratory.)

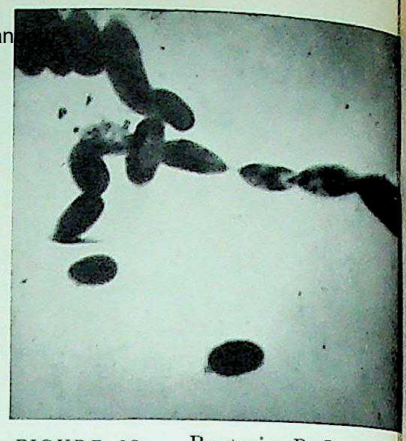


FIGURE 12 – Bacteria: B. fluorescens *Some internal structure visible.* (×6,000
(Taken with Metro-Vic instrument at the National Physical Laboratory.)

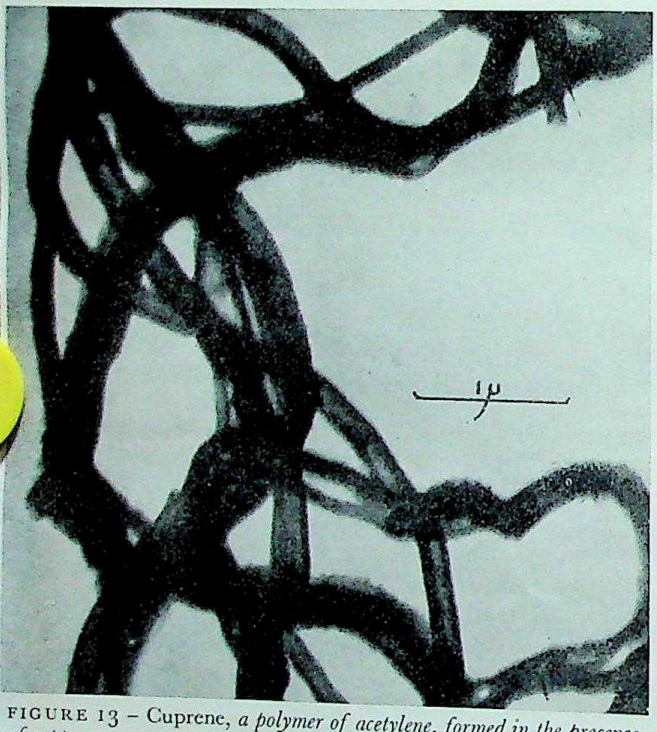


FIGURE 13 – Cuprene, *a polymer of acetylene, formed in the presence of copper.* *(Taken with the Toronto electron microscope.)* (×22,700)

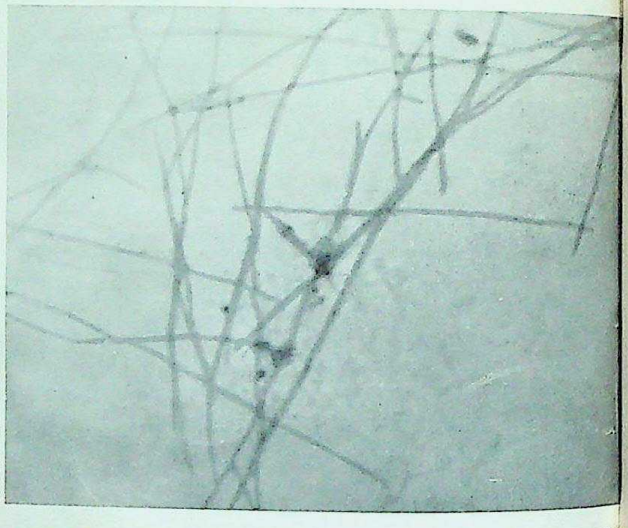


FIGURE 14 – Aucuba mosaic virus. *The virus responsible disease in tomato plants is seen to consist of long thread-like parti in this specimen prepared at Rothamsted Experimental Station.*
(Taken with R.C.A. instrument at the National Physical Laboratory.) (×30,0

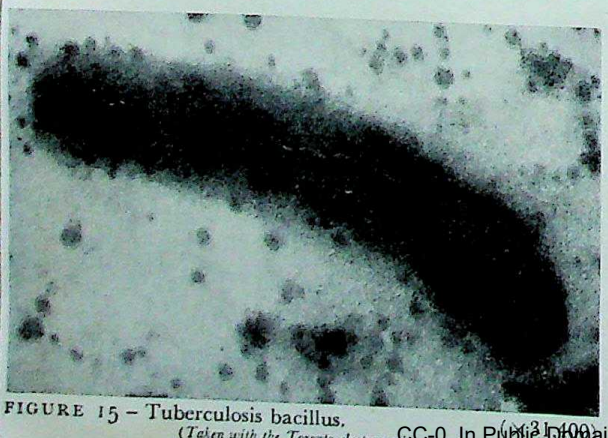


FIGURE 15 – Tuberculosis bacillus.
(Taken with the Toronto electron microscope.) (×31,400)

FIGURE 16 – Iron oxide particles.
(Taken with the Toronto electron microscope.) (×18,40

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

a glass lens, only more so. Thus if electrons of different velocities are present the images will be blurred and good definition will be impossible. It is also important to keep the currents in the magnetic lenses accurately constant, since on these depend their focal lengths.

SPECIMENS MUST BE THIN

The reader will have noticed that the electrons pass *through* the specimen in this type of microscope. Now electrons even of 45,000 volts energy have not much penetrating power; they would, for example, hardly get through tissue paper. But it is worse than this, for not only must the electrons get through the specimen, but they must do so without loss of speed, or the lens will fail to focus them properly for the reason we have just given. This reduces the permissible thickness to a few millionths of an inch if the picture is to show light and shade. Of course, a much thicker specimen can be used if all that is wanted is a silhouette of its edge or a picture of holes pierced in it (cf. figure 7), but in such a case the solid parts will appear completely black on a positive. Light and shade in a picture with the electron microscope, or indeed with an ordinary one for that matter, depend on differences in the scattering and absorption of the radiation by different parts of the specimen. In the case of the electron microscope a very small deflection is enough to turn the electrons out of the effective part of the beam, which is very narrow, and it is convenient to use a diaphragm with a hole in the middle to trap such unwanted electrons and let the rest through. Since many of them have lost speed in acquiring a deflection, they would blur the picture if included. Thus parts of the image which scatter strongly, like those which absorb, appear dark. The electron microscope has some advantage here over the optical, since slight differences in density affect the scattering power enough to reveal themselves, and it is not usually necessary to stain organic specimens.

This need for thin specimens is the most serious restriction of the present form of the electron microscope. In many cases, e.g. the study of smoke particles or of bacteria, it can be met by using a thin film of collodion or similar material supported on a disc with a small hole or on a very fine wire gauze. Such films are surprisingly strong, stand up well to bombardment by the electrons, and do not confuse the picture by showing a structure of their own. The actual specimens can often be conveniently mounted by suspending them in a drop of water on the collodion and letting the water evaporate.

For some organic objects this method fails, as the object is too thick by itself even without the collodion. Some improvement can be made by using faster, and so more penetrating, electrons. The R.C.A. are developing an instrument using 300,000 volt electrons. With this, Zworykin, Hillier, and Vance have been able to get a satisfactory picture of a section one or two thousandths of a millimetre thick of the body-wall of a cockroach. Theoretically the increased energy gives better resolving power also, but in practice it does not seem to have made any appreciable difference.

While it is possible to make metal films thin enough to give pictures even with 45,000 volts, for much of the work for which the electron microscope would be most useful in metallurgy it is necessary to use massive specimens. To get round this difficulty a number of ingenious devices have been used to prepare thin casts reproducing the surface of the metal, which can then be examined by transmission. In one method silver is evaporated on to the metal surface to be studied, and stripped off mechanically. Then collodion is flowed on to the silver, which is dissolved in acid, leaving the thin collodion film behind. This double process is found by Zworykin to give better results than applying the collodion directly to the original metal.

REFLECTION MICROSCOPES

Obviously devices such as these are subterfuges which are inconvenient and must tend to smudge out the finer details of the structure examined. Many attempts have been made to view objects by reflected electrons, but so far without very much success. If the object is viewed with its surface normal to the direction of sight, as in an ordinary microscope, the electrons, which must come from the sides, have to bend through a right-angle or more, and become so varied in energy that it is impossible to get an image. If, on the other hand, the object is both viewed and illuminated at glancing incidence, the electrons from the part in which one is interested get confused with those from parts before and behind, and in addition the view is very much foreshortened.

A very interesting attempt has been made by Ardenne to view solid objects by scanning,

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

something in the way that a television image is reproduced. To make the scanning fine enough, the electron microscope is in essence reversed, and a greatly *diminished* image of a small source of electrons is focused on the object. The electrons scattered from a very small region are then caught and recorded either as a spot of light of proportional intensity, or in some other way. By electric means the diminished image is traversed across the object, while the spot of light is moved in synchronism over a photographic film. The blackening of the line on the film will reproduce the variations in electron scattering by the regions of the object on which the electrons have fallen. When the electron beam has crossed the object once it is deflected slightly down and made to cross it again, thus covering the whole object as a page is covered with writing. All the time the spot of light records the scattered electrons on the corresponding part of the photographic film, which thus reproduces the scattering powers of the object with any convenient magnification. The resolving power depends on the ability of the reversed microscope to make a very fine scanning beam. So far this has been only moderately successful, but it clearly has possibilities.

PHOTOGRAPHIC STUDIES

Since the photographic action of fast electrons is the means used to record the image in an electron microscope, it is highly appropriate that the microscope has been used to study the action of the electrons on individual grains. It was known already that long exposure to electrons released metallic silver from silver bromide crystals of the emulsion even without development. The microscope shows that this silver is not uniformly distributed throughout the grain but concentrated in certain preferred patches. Something similar happens when the silver bromide crystals are exposed to very strong light. In this case the small patches of metallic silver probably reveal the latent image centres.

The action of developers can also be shown, and it is found that the silver in the developed grain is in the form of a mass of delicate filaments which may extend beyond the boundaries of the original grain. This is contrary to the view previously held that developed silver was a 'coke-like' substance. The appearance of the filament depends on the developer used; thus metol and amidol give very fine filaments, while those from hydroquinone are coarser. The very minute Lippman crystals of silver bromide, too small to be seen in an optical microscope, have also been studied. Each of these grows on development into a filament much larger than the original crystals.

BACTERIA

It is rather surprising, and fortunate, that bacteria stand up as well to the conditions in the electron microscope as they do. One would have been afraid that bubbles of gas would form in specimens exposed to a high vacuum and burst open the structure and, even if they escaped this, that the bombardment by the electrons would destroy the structure before it could be observed. In fact, they show up well and give good pictures without staining. Burton says that it is still uncertain if they are killed by the exposure. It is still too early for many results to have come out in this field of work, but a good beginning has been made. For example, the mosaic virus, which is responsible for a disease of the tobacco-plant, has been examined though it is quite impossible to see it in the ordinary microscope. This particular virus has been the subject of a brilliant series of researches by Dr Bernal using X-rays, and it is satisfactory that the size shown in the electron microscope confirms that deduced indirectly from the earlier work. This application of the electron microscope is the most exciting of all in the hopes that it holds out of providing a tool of the highest importance in medical research.

SMOKE AND DUST PARTICLES

A number of studies have been made of the structure of smokes. Smoke is a collection of solid particles, many of which are very small, three-quarters of them being invisible to the ordinary microscope. Figure 10 shows the curious shape of the particles in a smoke of zinc oxide formed by burning zinc in air. On the other hand, the particles in carbon black are rounded, and aggregate together in chains; those of aluminium oxide smoke are spheres and those of magnesium oxide mostly cubical, while iron oxide forms little prisms (figure 16).

Besides these artificial smokes, natural dust affords an important field for study, because of its importance in certain diseases such as miners' silicosis.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

THE ULTIMATE LIMITS OF VISIBILITY

One is naturally tempted to ask whether there is any hope of seeing individual molecules or even atoms in the electron microscope. Here a good deal depends on what is meant. In a certain sense each crystal of many substances, such as quartz, can be considered as a single molecule, if free from cracks and flaws. If one excludes these, which, of course, are easily visible, the next largest molecules are those either of very complicated organic substances such as some of the proteins, or of the polymerized substances now coming into such extensive use as plastics. From studies with the ultra-centrifuge it appears that some of the more complicated proteins have perhaps twenty thousand atoms in the molecule. If such molecules were solid cubical lumps they would have a side only 20 to 30 atom-diameters long, which would be near the limit for the present instruments. It is, however, much more likely that they have a more open structure so that their outside dimensions would be large enough to be visible. The difficulty is likely to lie in distinguishing them from the material which surrounds them or on which they rest, but in view of the success with microbes it may not prove insuperable.

In the case of the polymers we have relatively simple basic molecules which hook on to one another to form chains and aggregates of almost indefinite extent, as in a crystal, and it may not be an easy matter, or indeed have much meaning, to say where one compound molecule ends and the next begins. Nevertheless the study of these aggregated molecules by the electron microscope promises well. Figure 13, for example, shows the curious growth, like a tangled creeper, of one of these substances, the minute threads probably indicating an aggregation in the form of long chains.

Finally, individual atoms: to see an atom as a speck requires theoretically only sufficient illumination and sufficient contrast. Since a loose atom would move about with a high speed owing to thermal agitation, the atom must be anchored to something, which itself must be made of atoms. The best chance is presumably to have a heavy atom, e.g. of gold, on a support made of light atoms, e.g. collodion. The questions now are: can the atom be illuminated strongly enough to scatter a detectable amount of radiation (light or electronic), and if so, will this not be swamped by that scattered by the support? High resolving power helps, because electrons scattered by the part of the support outside the unresolved range will be focused on other parts of the photographic plate and cause no confusion. The less the region unresolved and so indistinguishable from the atom, the more chance there is that the electrons scattered by the atom itself are a sufficient proportion of the whole number in the region to make this part appear appreciably darker than where there is no heavy atom. Assume a film of celluloid about 100 carbon atoms thick, which is feasible; then if the resolving power were such as to isolate a square 5 atoms each way there would be 2,500 carbon (or oxygen) atoms whose scattering would mix with that of the gold. But the gold weighs some sixteen times as much as a carbon atom, and the scattering is roughly as the weight, so the gold would cause about 1 part in 150 extra scattering. This is a little too small to detect, and we have assumed a better resolving power than is feasible at present, but the experiment looks the kind of thing that may well be successful in the next ten years. To see the component parts of an atom is quite another matter. Here one is up against the fundamental difficulty that electrons, fast enough to have the necessary resolving power, will knock the atom about so much that what one would see would depend as much on the accidents of the collisions as on the original character of the atom. This theoretical limitation, however, does not prevent the electron microscope from being the most promising aid to research in more than one branch of science that has been discovered in the last few years.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Nicolaus Copernicus, 1473—1543

H. DINGLE

Exactly four hundred years ago, the Polish astronomer Nicolaus Copernicus received on his death-bed the first copy of his book *de Revolutionibus Orbium Coelestium*. In the present article, Professor Dingle traces the course of early cosmological theory, and shows that though the progress of Copernicus's conception was slow, his book marked the turning-point of European thought into the scientific channel.

In the history of European thought a few dates stand out as points almost of discontinuity, certainly of abrupt change, and of these 24th May, 1543, is one of the most prominent. On that date, Nicolaus Copernicus received, as he lay dying, the first printed copy of his book, *de Revolutionibus Orbium Coelestium*, which was destined to provide a new basis for astronomy and for the general philosophical outlook by which man's reaction to the world of experience is ultimately determined.

Copernicus was a Pole by birth and probably—though German writers, since his greatness has been recognized, have claimed otherwise—by descent. He was born on 19th February, 1473, at Toruń (Thorn) on the Vistula, where he went to school and whence he proceeded to the University of Cracow, then one of the most famous centres of European culture. Probably through the influence of his maternal uncle, Lucas Watzelrode (under whose care he had passed at the age of 10, on the death of his father), he decided to enter the service of the Church. Watzelrode was a man of considerable strength of character, who had become Bishop of Ermeland during Copernicus's youth and who sought to obtain for his nephew a canonry at the Cathedral of Frauenburg. His first attempt failed, and accordingly Copernicus, on leaving Cracow, proceeded to Bologna to continue his studies in preparation for a more successful attempt to be made later. He remained at Bologna for four years, and although the canonry was obtained during this period, he followed up his sojourn there by further study at Padua, Rome, and Ferrara, returning ultimately to Ermeland in 1506 after some ten years of almost continuous study in Italy.

There can be little doubt that the foundations of his new astronomical ideas were laid during this period, though his studies were not primarily in astronomy. The duties of a canon were manifold, and Copernicus studied law and medicine chiefly, though he evidently gave much thought to astronomical matters, and taught mathematics during his year's residence in Rome. The Professor of Astronomy at Bologna was Novara, a man of original ideas, and we are told that Copernicus worked with him 'not so much a pupil as a helper and witness of the observations.' Copernicus also studied Greek, and in later years published translations into that language of Latin verse. At some time during his career he became proficient in painting, but no specimen of his work survives. He was thus a man of wide interests and attainments, but it is clear that, from an early time, Urania, the Muse of Astronomy, had marked him for her own, and to her he remained faithful to the end of his life.

It was a time of considerable political upheaval, and in the wars between the Poles, the Prussians, and the Teutonic Knights, Ermeland became the centre of much disturbance. Copernicus, in addition to his clerical and medical duties (he was continually called upon to minister to the bodily health of successive bishops and the poor of the diocese), found himself charged with the military defence of his district, which he undertook and prosecuted with some distinction. At the subsequent peace conference he was entrusted with the care of its interests, and when difficulties arose through debasement of the coinage, he made an analysis of the principles of currency, on the basis of which new legislation was established which remedied the evil.

During all this time, however, his new astronomical system was his chief and abiding interest. He tells us in the preface to *de Revolutionibus* that he had worked at it for some thirty years, and the Polish scholar Birkenmajer has traced out, from notes on scraps of paper, margins of books, and even on walls, as well as from the successive amendments of the MS. of *de Revolutionibus*, the growth and gradual modification of his ideas.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

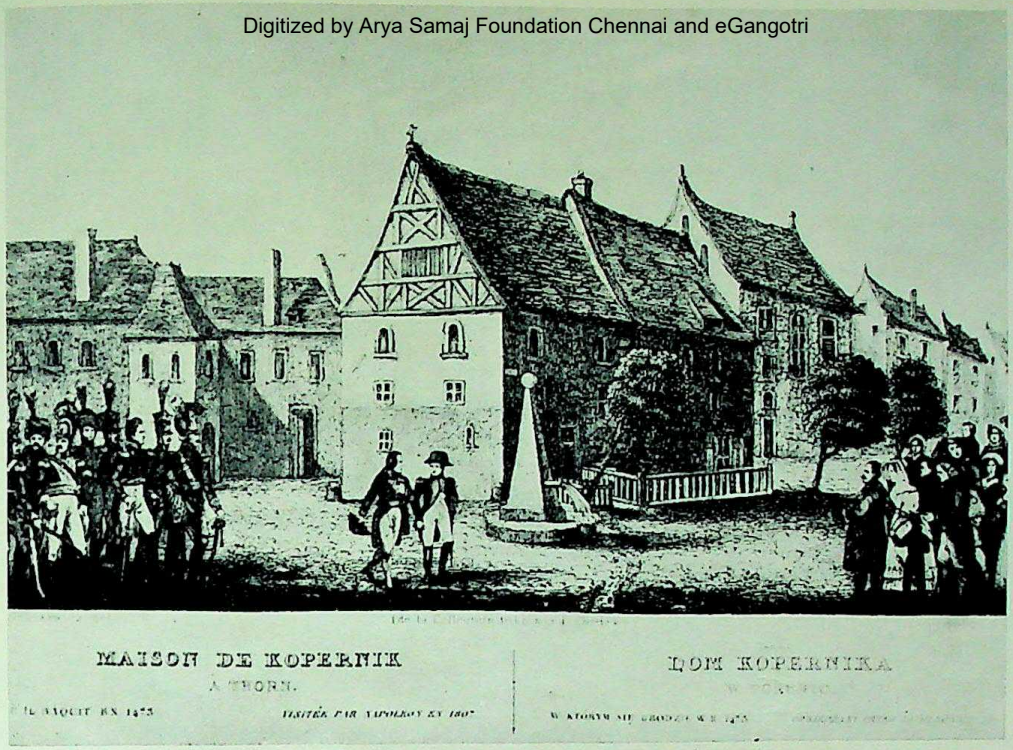


FIGURE 1 – (*top*), *Copernicus's house at Toruń* (*Thorn*) *during Napoleon's visit in* 1807.

(The above and the other illustrations throughout the article are by courtesy of the Polish Ministry of Information.)

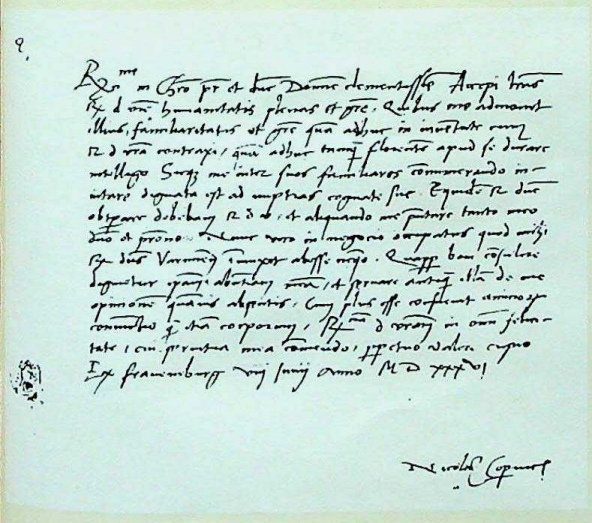


FIGURE 2 – (*centre, left*), *Copernicus's handwriting.*

NICOLAVS COPERNICVS TORNAEVS BORVSSVS MATHEMAT.
NAT. ANNO 1473 OB. 1543.
Non docet instabiles Copernicus aetheris orbes,
Sed terrae instabiles arguit ille vices

FIGURE 3 – (*right*), *Copernicus—a portrait from the Rapperswill collection in the National Library at Warsaw.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 4 – *Copernicus monument, by Thorvaldsen, in Warsaw. The inscription, which means 'Nicolaus Copernicus: His Fellow-countrymen,' has been altered since the German occupation to 'Nicolaus Copernicus: The German Nation.'*

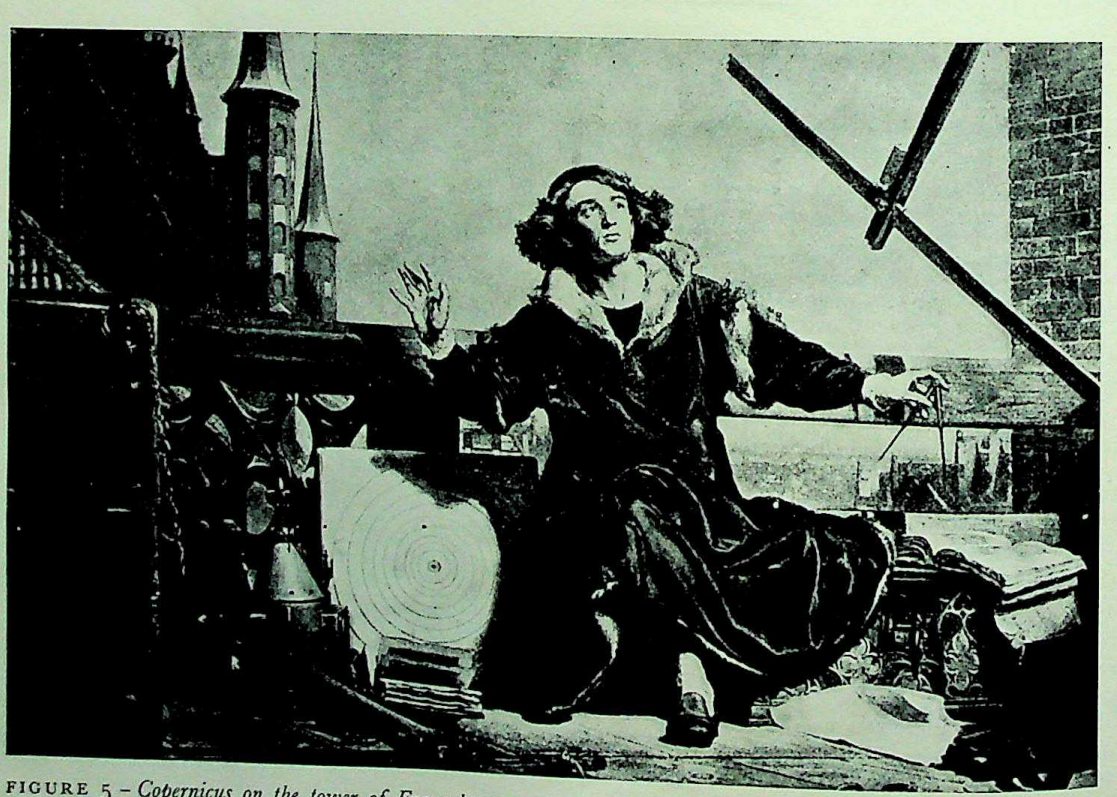


FIGURE 5 – *Copernicus on the tower of Frauenburg.*

(From the painting by J. Matejko.)

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Occasionally he made observations of his own, but he was primarily a thinker, not an observer, and was always ready to accept with respect—perhaps too much respect—the observations of earlier astronomers. He was of a retiring disposition, and despite the promptings of his friends and admirers he hesitated long before publishing his great work. He consented only towards the end of his life, after his young and enthusiastic pupil, Rheticus, who had remained with him for two years studying his manuscript, had, with his permission, published a preliminary account of the work. He had, however, long previously circulated in manuscript form a *Commentariolus* containing a short résumé of his ideas, which were thus well known among astronomers.

To understand Copernicus's work we must know something of the prevailing astronomical and philosophical ideas of the time. These ideas had their source in Aristotle, in whose system of the universe the earth occupied the central, stationary position, while the heavenly bodies were attached to material spheres which revolved ceaselessly with uniform motion round it. The motion of any particular body might be the resultant of the motions of several spheres, for they could communicate their motions to one another. The fixed stars were all attached to the outermost sphere, and their motions, being observed to be simple and uniform, needed no interference from other spheres. The planets, however, including the sun and moon, appeared to move irregularly, and their paths had therefore to be represented by combinations of uniform circular motions. In Aristotle's day, when observations were not very exact, this could be done well enough with fifty-five spheres.

This geometrical system, however, was supplemented by certain physical—or, as we should say, metaphysical—ideas. The material below the lunar sphere, consisting of the four 'elements' earth, water, air, and fire, was changeable and corrupt. It tended to move in straight lines, either towards the centre of the universe by gravity, as with earth and water, or away therefrom by levity, as with air and fire. Such motion could not be eternal, for it had to end when the centre or the outermost sphere was reached, the universe of Aristotle being essentially finite. Celestial matter, however, of which the spheres and the heavenly bodies were composed, was of a more perfect kind, not subject to change and decay, and partaking only of the perfect, eternal, circular movement. In the years which followed, these physical principles were accepted as necessary conditions to which all theories of the structure of the universe must conform, but the steady accumulation of observations made it necessary to modify the system of spheres which Aristotle had found adequate.

By the time of Ptolemy, in the second century A.D., a very different architecture of the universe had become established. Except for the sphere of the fixed stars at the outer boundary of the universe, the perfect material spheres had fallen into neglect and their places had been taken by imaginary circles. Each planet moved on a circle whose centre moved on another circle, and so on, until finally a circle was reached whose centre was stationary with respect to the earth, though not necessarily in it. This ultimate circle was called a *deferent* and the others *epicycles*, and the problem was to conceive a system of such circles which would produce the observed movements of the planets. This was a geometrical problem, and it engaged the best minds of the ancient world. The results of their labours were collected by Ptolemy in his famous *Syntaxis*, or *Almagest*, which embodied the main principles of the astronomy of the next 1,400 years.

As, in the succeeding centuries, observations became more numerous and more exact, modifications of detail were made to adapt the system to the demands of fact—to 'save the phenomena,' as the phrase went. Another problem which developed increasing urgency was that of reconciling the Ptolemaic circles with the Aristotelian spheres, for the authority of Aristotle during the Middle Ages acquired almost the status of divine sanction. Ptolemy had ignored the spheres, but, on the other hand, he had not attached too much weight to the circles. He regarded them as merely a geometrical device, without 'reality,' and he would probably have accepted the spheres as real, though not helpful in saving the phenomena. Subsequent thinkers, however, could not contemplate without uneasiness a philosophy in which the real was useless and the useful imaginary. On one thing all were agreed, namely the sovereignty of the Aristotelian physics—the distinction between the incorruptible heavens and the corruptible earth, and the necessity that all celestial movements should be compounded of uniform circular motions. Despite ingenious efforts, the divorce between reality and practicability remained a thorny problem, and, moreover, as observations accumulated it became increasingly difficult to save the phenomena with any

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

reasonably simple combination of circles. Such was the state of affairs to which the young Copernicus turned his attention, with a mind awakened to new possibilities by the general spirit of the Renaissance and the particular influence of Novara.

Copernicus accepted the Aristotelian metaphysics with absolute fidelity. He adopted also the traditional eccentrics, deferents, and epicycles as proper geometrical means for representing the phenomena. Furthermore, he accepted the outermost sphere of the fixed stars at a finite distance from the earth. Where he differed from Ptolemy and the general practice of his time, however, was in his rejection of certain devices which, in his view, kept the letter of the Aristotelian rules at the expense of their spirit, and which accordingly made the mechanism of the heavens much more complicated than he considered to be consistent with their dignity. In particular, Ptolemy had regarded a body as moving 'uniformly' in a circle if its angular velocity about *any* internal point was uniform, whether or not that point was the centre of the circle. Copernicus was not satisfied with this, and looked for some way of avoiding it.

He found it in the abandonment of the idea that the earth was stationary. If, instead, the sun were supposed at rest and the earth given certain movements to account for some of the apparent movements of the stars and planets, then not only could strictly uniform motion be preserved, but also the phenomena could be represented by a very much simpler combination of circles. Moreover, the circles would then all move in the same direction instead of some in one direction and some in the other, the general principle of uniformity thus being obeyed in still another particular. By this one change—the change of standard of rest in the universe—Copernicus was able to reduce the number of celestial circles from over eighty to thirty-four. The movements given to the earth were, first, a daily rotation on an axis, to account for the rising and setting of the heavenly bodies; second, an annual revolution round the sun, to account for the apparent movement of the sun along the ecliptic and the retrograde movements of the planets; and third, a conical movement of its axis, to account for the precession of the equinoxes and certain illusory effects which, with others of his time, he believed to be real.

The immediate objection to this change was not aimed, as is commonly believed, at its impiety, but at its absurdity. If the earth rotated, it was said, clouds and bodies thrown into the air would be left behind and fall far to the west, and the great speed of its motion would cause it to fly to pieces. Copernicus could only partly answer these arguments, for the foundations of dynamics still awaited the labours of Galileo. To the objection that the earth's revolution round the sun would require an apparent 'parallactic' movement of the stars, Copernicus replied that such a motion must indeed exist, but owing to the smallness of the earth's orbit compared with the distance of the stars, it was unobservable. This, of course, was the true explanation, but the movement remained undetected for 300 years, though in the meantime other evidence of the earth's revolution had come to light. On the whole, however, the chief evidence for the Copernican system at the time of its origin was the great simplicity it introduced into the description of the heavenly motions; there was little or nothing of a decisive physical character that could be advanced in its favour.

For this reason, the problem which agitated the immediate successors of Copernicus—namely, was the Copernican universe real or only the simplest geometrical means of saving the phenomena?—was by no means an easy one. What Copernicus himself thought on the matter is uncertain, though he doubtless regarded his system as the best means of saving the phenomena. Before publishing his book he wrote a letter, which has been lost, to his friend, Andreas Osiander, which evidently bore on the subject, for Osiander in his reply advised Copernicus to insert a preface stating that hypotheses such as that to be proposed were not articles of faith but bases of calculation, and that it did not matter if they were false so long as they represented the phenomena. When the book appeared it contained such a preface, but it was unsigned and later was found to be the work not of Copernicus but of Osiander, who had seen the book through the press.

There is no doubt that Osiander's object was to placate theologians and philosophers, who, he feared, would regard the book as contrary to the sacred Scriptures. We cannot, however, assume that Copernicus shared this fear. The Pope had heard of the system and had accepted dedication of the book to himself, and high dignitaries of the Catholic Church had urged its publication, one of them, the Cardinal Bishop Schönberg, contributing a foreword. It is not likely, therefore, that Copernicus would have feared suppression, and he tells us, in fact, that it was fear of the ridicule

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

of the unlearned that had delayed publication. Osiander, on the other hand, was a rather obscure Lutheran, and Luther and Melanchthon had spoken scathingly of the Copernican system, so it is natural that he should wish to defend his adherence to it. There was, in fact, no formal religious objection to the work until long after Copernicus's death, when other questions had arisen to complicate the matter. It was not until 1616, seventy-three years after publication, that *de Revolutionibus* was placed on the *Index*.

In the astronomical world, however, the progress of the Copernican conception, though slow at first, was continuous. It was essential to the work of Kepler, who discovered the elliptical form of the planetary orbits, and to the subsequent work of Newton, which everyone knows. In 1943 we can see that, beyond all question, the book published in 1543 marked the turning-point of European thought into the scientific channel.

Correspondence

(*Continued from page* 124)

THE PLACE OF SCIENTISTS IN THE COMMUNITY (*continued*)

maintain even their present standards of living, scientific and technological research will be needed on a greatly extended scale during and after the period of reconstruction. By such means, and by such means only, can we hope to keep our place as one of the leading nations in the modern world, and since there is very generally some time-lag in the applications of research, the importance of an immediate preparation for the period of reconstruction is urgent.

While, however, the importance of scientific research and of the applications of science in securing industrial prosperity cannot be over-emphasized, there are many responsible scientists who view with some concern the exaggerated claims, which are frequently made by some who profess to speak for science, that all would be well if only a larger proportion of the national income were expended on scientific research and if men of science were given a position of special authority in the affairs of the State. Such claims, we believe, can only foster illusions and be the cause of future disappointment.

The claim sometimes made that the scientist, as scientist, should be given a position of exceptional authority in deciding the policies of governments is one which a democratic community cannot and should not accept. By searching out the facts and by suggesting remedies based on the facts, the man of science can give very valuable assistance in solving many of the problems which face society, and his help should be sought much more frequently and fully than has been the case in the past. Social problems, however, involve not only material but also moral and spiritual values, and are too complex to be solved solely by the methods of science or by any one type of mind. It is the duty not of the scientist, as scientist, but of the community of which he is a member, to weigh the different factors and to make a decision. No despotism could be worse than that of a scientific and soulless technocracy.

[*In view of the controversies associated with the subject of this letter, it was felt that a statement of another point of view was advisable, and Professor J. B. S. Haldane was invited to comment on the letter.* ED.]

From J. B. S. Haldane, M.A., F.R.S.

It is unfortunate that the signatories of the letter on 'The Place of Scientists in the Community' do not state who holds the views which they summarize in the second paragraph, and then attack. I have never met such a person, but am prepared to believe that such exist. Nevertheless I believe that our society (under whatever economic system) would be more efficiently run if a substantial fraction of our rulers were scientifically trained.

The present Government includes one professional scientist and a large number of lawyers. Do the signatories honestly believe that scientists are more 'soulless' than lawyers? Even if they do so, is it not possible that we should be better off if, during the last twenty years, one Chancellor of the Exchequer had been a professional statistician, one Minister of Agriculture a biologist, and one Secretary of State for Air a physicist? The signatories all combine administrative and scientific ability. They have all sacrificed time from research to work in organizations. Men with just such abilities could, and I believe should, play a larger part in government.

Scientists should not confine themselves to giving help on technical matters when asked. Their special knowledge enables them to detect evils and to suggest remedies which are not obvious to others. In so far as they can do this it is not merely their right, but their duty as democrats, to ask their fellow-citizens to put them in positions 'of special authority in the affairs of the State,' for example in Parliament. Members of other callings have similar rights and duties. When, if ever, there are as many scientists as lawyers or company directors in the Cabinet, it will be time to talk of the dangers of a 'scientific technocracy.' Till then, scientists need not, and should not, avoid political activity.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Forests of the sea

F. E. FRITSCH

The variety and profusion of the marine flora are very inadequately appreciated by the average man and woman, to whom, as often as not, seaweed is just seaweed. Professor Fritsch's article indicates that the forests of the sea are comparable in interest with those of the land, and contain a multiplicity of striking forms—some of giant dimensions.

The brown seaweeds that densely clothe the rocks between tide-levels (figure 1) on the British and other northern shores mainly comprise the bladder and serrated wracks (*Fucus vesiculosus* and *F. serratus*), often accompanied by the slightly larger *Ascophyllum*, with strap-shaped fronds dilated by occasional air-bladders. The daily exposure to drying and temperature extremes is probably responsible for the relatively small size of these seaweeds. *Fucus* plants rarely exceed a yard in length, and are small compared with the oarweeds (*Laminaria*) that occupy the permanently submerged shore-line, so that they are uncovered only at low water of spring tides (figure 2). Members of the oarweed group, or Laminariales, are important elements of the marine flora in colder seas all the world over, and they are remarkable for their large dimensions, as well as for their customary growth in dense communities, which may aptly be compared with the forests of the land.

The flexible stalk or stipe of the oarweeds bears a simple (figure 3) or divided blade. The plants often reach a length of 4 or 5 yards, while the stalks of older individuals may be an inch across and show growth-rings like the trunk of a tree. Certain Norwegian and American Laminarias are appreciably bigger, while some of the Pacific Laminariales are among the largest plants known. Growing as they do in extensive beds in several fathoms of water, they commonly constitute natural breakwaters, reducing the erosive action of the sea on the adjacent coast.

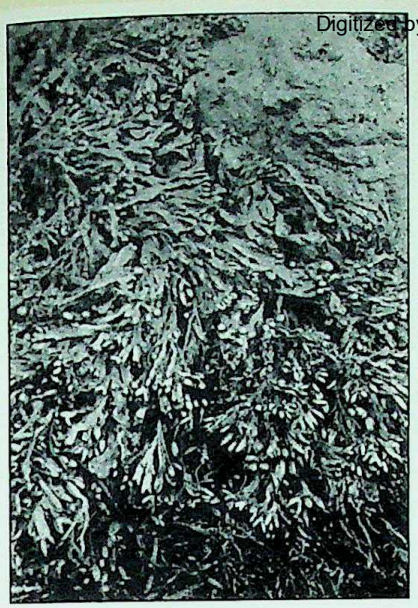
Most oarweeds are perennials, the stalk becoming longer and thicker year by year, while each spring a new blade arises from a formative region at the top of the stalk (figure 4) and replaces that of the previous season. The new blade is always undivided and remains so in some oarweeds (figure 3), but in others (e.g. *Laminaria digitata*) it develops successive splits (figure 4), which, extending to the margin, divide the greater part of the blade into narrow segments, the whole ultimately resembling a huge many-fingered hand. In all Laminariales the young plants have short stalks and simple blades, and the various forms exhibited by the adult seaweeds are mostly due to the formation of similar splits, which may also extend into the stipe, so that the individual blades frequently have short stalks of their own.

Among the many striking forms found in other oceans, one of the most noteworthy is the bull-kelp (*Nereocystis*, figure 5), with a stipe that may be 40 yards long, while the numerous blades are supported near the surface by the large float which alone is visible from the shore (figure 6). This annual, which appears about February and lasts into the following winter, illustrates the rapid growth observable in these giant seaweeds. The similar elk-kelp (*Pelagophycus*), so called because the blades are distributed along two horizontal branch-stalks situated above the float, is restricted to California. Both it and *Nereocystis* often get carried out to sea in rough weather and may be found drifting miles away from the nearest mainland. *Pelagophycus*-drift is so regularly encountered off the Californian coast that the Spaniards took is as a trustworthy token of the proximity of land and adjusted the ship's course as soon as it was sighted.

Along the whole western coast of America there are huge tracts of *Macrocystis* (figure 7), although its chief home is in South Temperate and Antarctic seas. Here flotation is secured by the small air-bladders situated at the bases of the crowded 'leaves' (figure 8). The possession of such floats, as well as the buoyant properties of the water, enables these forms to expose their blades near the surface, where they can obtain the light-energy required for building up their substance from the carbon dioxide absorbed from the water. Certain smaller Laminariales have stronger stalks so that they remain upright even when unsupported. This is so in the sea-palm (figure 9), the dense

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri



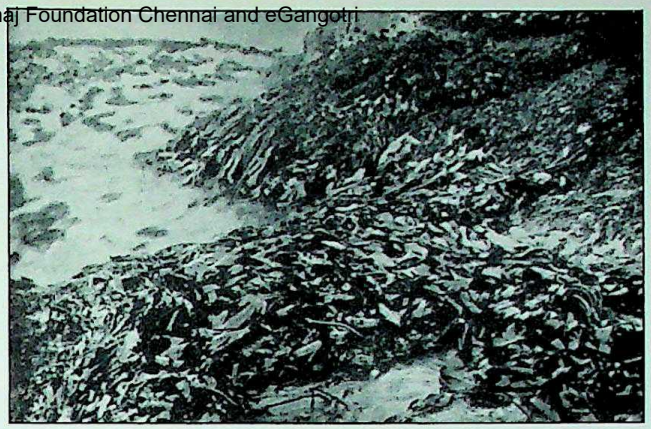


FIGURE 2 – *At low tide luxuriant growths of large oarweeds (especially* Laminaria digitata*) are sometimes exposed, as in the photograph. Another species of oarweed that inhabits deeper water is just visible above the surface of the sea on the left. The photograph was taken on the shores of The Faeroes by Dr F. Boergesen.*

FIGURE 1 – *Attached to the rocks (between tide-levels) on temperate shores one finds a profuse growth of various fucoids. The photograph, taken by Dr F. Boergesen in The Faeroes, shows a dense mass of the bladder-wrack* (Fucus vesiculosus)*, with a little* Ascophyllum *appearing near the base.*

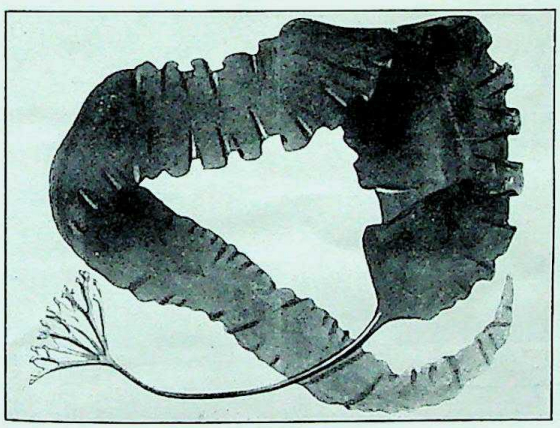
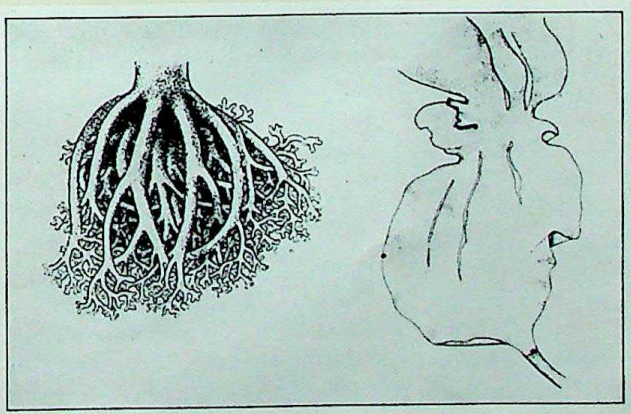


FIGURE 3 – *The photograph (after Harvey) shows a small individual of the simple-bladed oarweed* (Laminaria saccharina) *reduced to about one-sixth. As in all members of the oarweed group, the plant consists of a basal attaching organ, a stalk, and a long leafy blade.*

FIGURE 4 – *By means of their richly branched holdfasts, one of which is represented on the left, the oarweeds gain a firm hold on the rocks. Plants cast up after storms are often intact, with fragments of rock still clinging to the holdfasts. The right-hand figure shows the new season's blade of a digitate oarweed arising beneath the remains of the old: the first splits are visible in the new blade. (After Sauvageau and Setchell.)*



CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

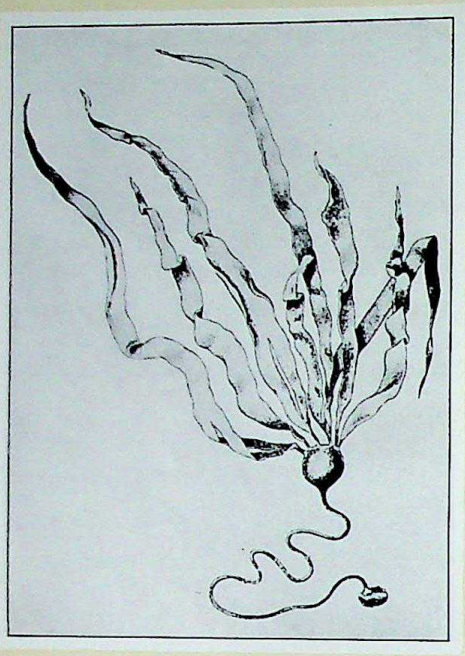


FIGURE 5 – *The bull-kelp* (Nereocystis), *one of the biggest of the seaweeds, occupies large areas of the sea-bottom off the Pacific coasts of North America; it grows in* 8–10 *fathoms of water. The blades that arise by progressive splitting are held at the surface by the huge float situated at the top of the stalk. This is a relatively young plant (after Postels and Ruprecht); older ones have much thicker stalks and more numerous blades.*

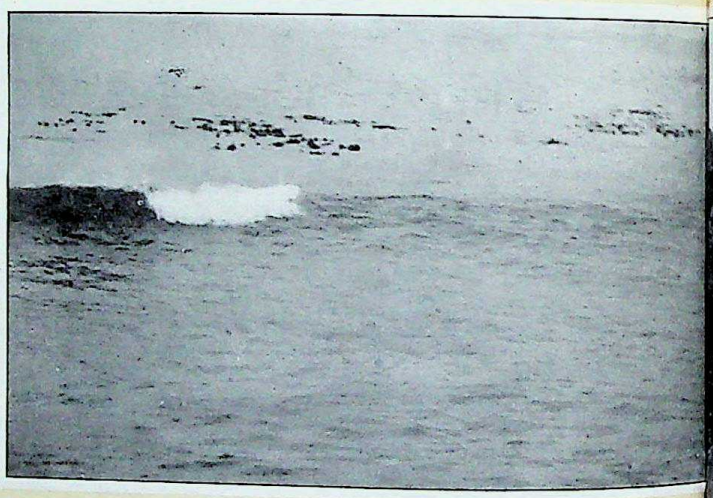


FIGURE 6 – *Seen from the sh the floats of the numerous Ner cystis plants appear as dark jects, bobbing up and down u the play of the waves.*

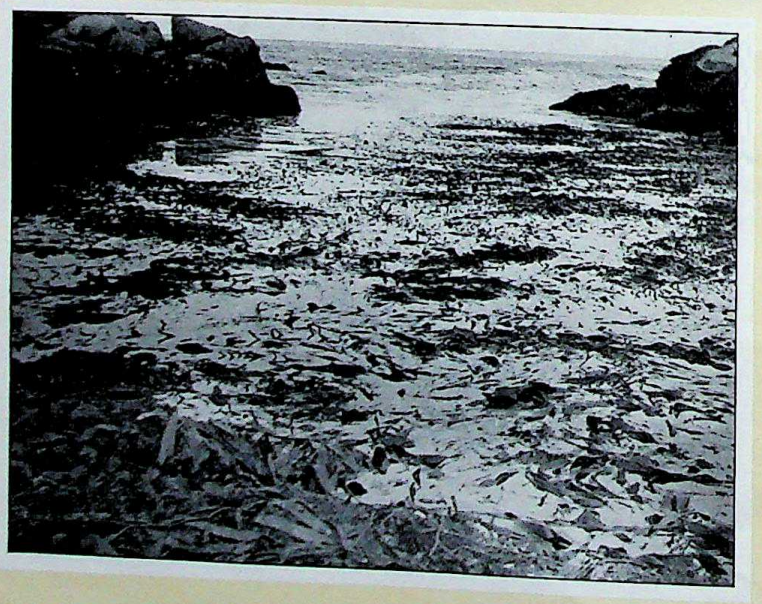


FIGURE 7 – *The largest of the extra-European Laminariales is* Macrocystis, *which may reach a length of* 200 *ft. from end to end. It is abundant off many parts of the shore of California (where the photograph was taken), forming extensive beds that act as natural breakwaters.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

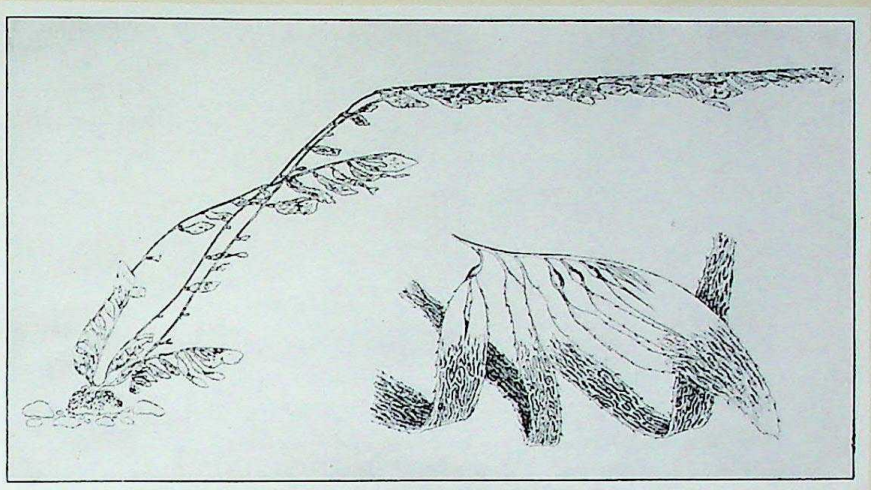


FIGURE 8 – *The slender stalks of* Macrocystis *rise obliquely to the surface of the sea, where they trail out for long distances, floating with the help of small bladders situated at the bases of the numerous serrated fronds. Only these floating portions are visible in the preceding photograph. From the scimitar-shaped tip of the floating stalk (right-hand figure) the numerous blades are split off progressively. (After Skottsberg.)*

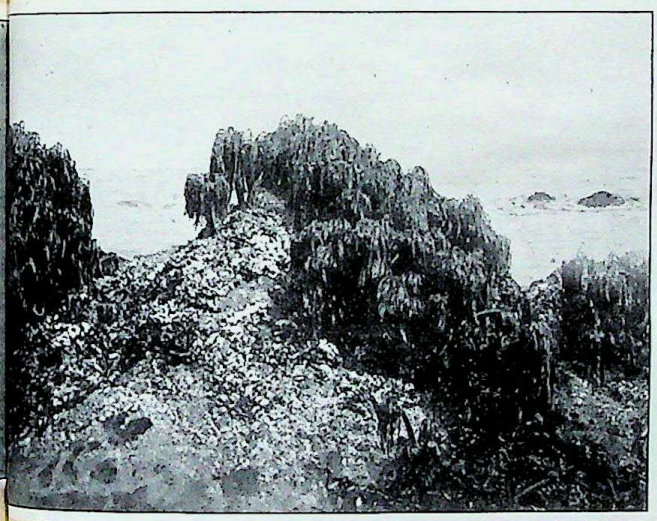
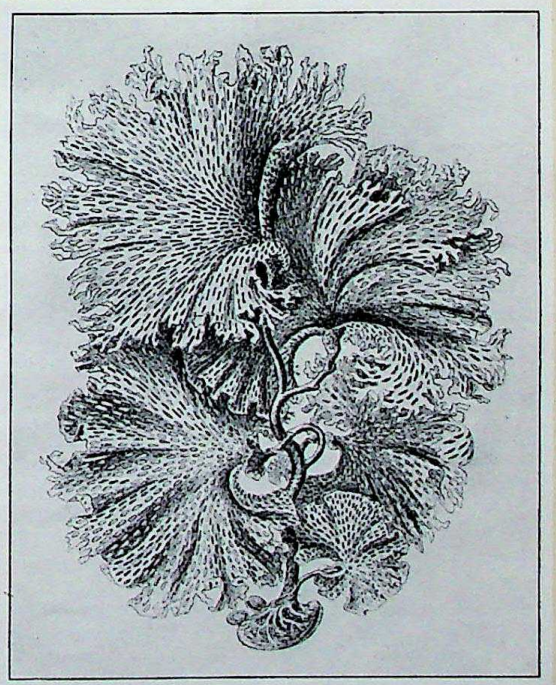


FIGURE 9 – *The sea-palm* (Postelsia) *is a much smaller form growing gregariously just above low tide level on the coasts of the Pacific (North America). Here the thick sturdy stalk stands erect, and, when uncovered by the sea, the numerous blades hang down alongside it. The plants reach a height of about* 18 *in.*



RE 10 – *One of the most remarkable seaweeds of the oarweed is the Arctic* Thalassiophyllum, *growing to a height of about a . The firm, twisted stipe bears a number of blades, rolled up along dge like a cornet and perforated by numerous regularly arranged holes. er Postels and Ruprecht.)*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

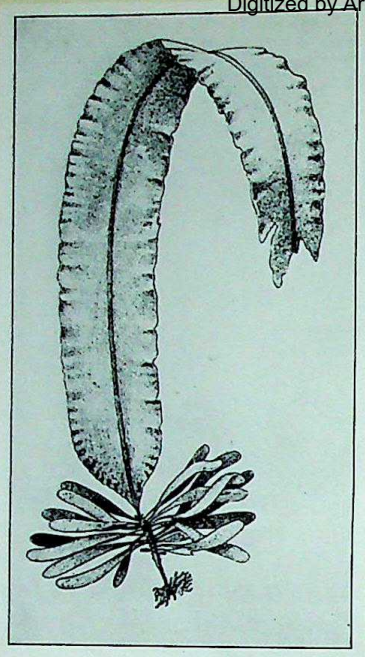


FIGURE 11 – *Among the largest of northern seaweeds are the Alarias, in which the rather short stalk puts out each year a number of outgrowths which bear the reproductive organs. Both they and the thick rib which stiffens the long blades are items of human diet in various parts of the world.* (*After Kjellman.*)

FIGURE 12 – *The seaweed* Egregia *forms extensive meadows at and below low tide level on the Pacific coasts of North America. The long drifting and sparsely branched stalks are closely beset with small leafy blades, and also bear occasional floats.*

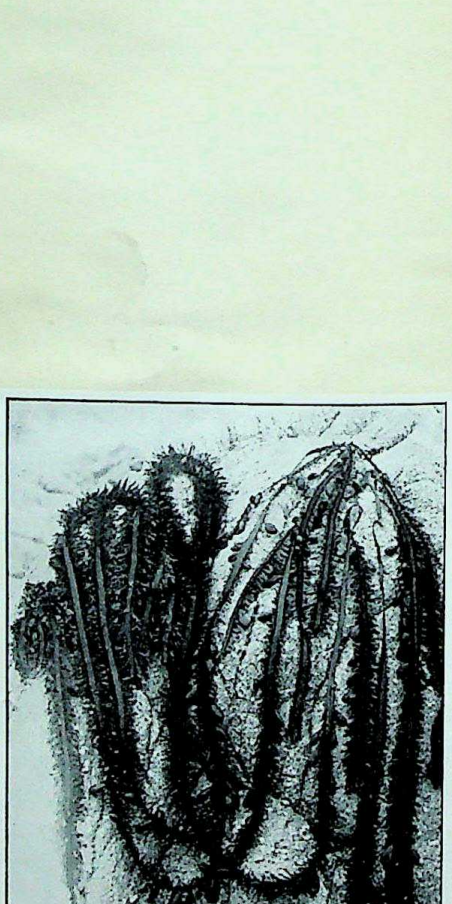


FIGURE 13 – *This plant of* Egregia (*not inaptly called the feather-boa kelp*) *was about* 6 *yards long. Note the floats which enable the fronds to drift at the surface.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

growths of which are quite unaffected by the buffeting of the Pacific breakers. In the Antarctic Lessonias, the sturdy stipes (up to 3 yards long) may be as thick as a human thigh and, when the numerous blades have decayed, the stipes of cast-up plants look deceptively like logs of wood.

The repeated splitting of the blades that occurs in these diverse forms affords a large surface for light-absorption, and at the same time one that yields readily to the play of the waves. Other Laminariales exhibit a different device, namely the formation in the enlarging blades of numerous holes through which the water can flow. This is so in the Arctic Agarums, where the blade is undivided, as well as in *Thalassiophyllum* (figure 10), which forms small submarine forests in the Bering Sea and off the shores of Alaska.

All Laminariales propagate by motile cells that give rise to a microscopic generation producing the new seaweed. The reproductive cells are formed in crowded receptacles covering large areas of the ordinary blades. In the Alarias, however, they are restricted to special outgrowths formed on the short stalk (figure 11). The vegetative blade grows to great lengths; in the British *Alaria esculenta* it may be more than 6 yards long, while in the Pacific *A. fistulosa* it may reach 25 yards, with a width of 6–7 ft. In *Egregia* (figure 12) the plants consist almost entirely of the flattened stipes which produce innumerable leafy outgrowths (figure 13), while the original blade remains quite small.

Both the intertidal fucoids and the *Laminarias* have long been used as manure, their value in this respect being partly due to their high content of potassium. Before the exploitation of the Stassfurt deposits, the ash or kelp obtained from such seaweeds after burning indeed furnished the chief source of potassium and was extensively used in the preparation of soap and glass. It also afforded iodine, in which *Laminaria* is particularly rich. The kelp industry was widespread in Northern Europe, and in France the rivalry between those collecting the seaweed as manure and those burning it for ash became so violent that its use had to be regulated by statute. More recently, the algin derived from the mucilage of *Laminaria*, *Nereocystis*, etc., has been put to various uses, as for instance in the making of adhesives and of a kind of artificial silk, and there can be no doubt that there will be a wider exploitation of brown seaweeds in the future. Near Puget Sound (U.S.A.) the annual production of *Nereocystis* has been estimated at some 200,000 tons, while the kelp beds on the Californian coast are stated to cover about 400 square miles, producing annually 59,300,000 tons of fresh kelp. The Laminariales do not provide much human food, although Alarias are so utilized in various regions, and the Japanese prepare a diversity of food products from Laminarias.

Research activities in China

As the highest research organization under the Chinese National Government, the Academia Sinica, despite the limitations on its finances, personnel, and equipment, has carried on an extensive programme throughout Free China. It maintains ten institutes: those of Physics, Chemistry, Engineering, Geology, Astronomy, Meteorology, Zoology and Botany, Psychology, History and Philology, and the Social Sciences.

Until July 1937 the first three were situated in Shanghai, while the central office and the other seven institutes were all in Nanking. At present, the central office is temporarily in Chungking; the institutes of Zoology and Botany, Meteorology, History and Philology, and Social Sciences are in two localities in Szechuan; the institutes of Chemistry, Astronomy, and Engineering are in Kunming; and the institutes of Physics, Geology, and Psychology are in Kweilin.

The National Research Council was organized as a part of the Academia Sinica in 1933. Its function is to promote and co-ordinate scientific research in the whole country, the word 'scientific' being used in the wider sense, including the social and historical sciences.

Members of the council consist of the president of the Academia Sinica, the directors of its research institutes, and thirty members elected by professors of national universities. The term of office of the elected members is five years. The council ordinarily meets once a year.

The Academia Sinica was founded in 1928 in Nanking with the late Dr Tsai Yuan-Pei as its president. After his death in March 1940, the National Government appointed Dr Chu Chia-Hua acting president. During the period 1939–41, H. C. Zen and Fu Sze-Nien successively served as secretary-general. The latter resigned in the autumn of 1941 and Dr Yeh Chi-Sun, professor of physics in the National Chinghua University, was appointed to the post.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The electrometric determination of *p*H and some of its applications

H. T. S. BRITTON

The precise measurement and adjustment of hydrogen-ion concentration have had considerable value in many industrial, commercial, and agricultural operations. Their use in the problems of pure inorganic chemistry, while less spectacular, is of equal importance, as Professor Britton indicates by the consideration of some typical examples.

PRINCIPLES

In recent years much attention has been devoted to the importance of hydrogen-ions in chemistry and in many industrial processes. The object of this article is to discuss briefly the significance of *p*H and its measurement and to give an idea of how *p*H determinations have assisted in the solution of some chemical problems.

As water constitutes a system in which the equilibrium $H_2O \rightleftharpoons H^{\cdot} + OH'$ is governed by $K_W = [H^{\cdot}]\,[OH']$, it follows that the concentration of hydrogen-ions, $[H^{\cdot}]$, is related to that of the hydroxyl-ions, $[OH']$, by $[H^{\cdot}] = K_W/[OH']$, which applies to all aqueous solutions. A convenient method of expressing hydrogen-ion concentration is that introduced by Sörensen in terms of *p*H, which is the negative power to the base 10 of the hydrogen-ion concentration, i.e. $[H^{\cdot}] = 10^{-pH}$, or $pH = -\log_{10}[H^{\cdot}]$. For pure water, $[H^{\cdot}] = [OH']$, and therefore $[H^{\cdot}] = \sqrt{K_W}$. At ordinary temperatures $K_W = 10^{-14}$ approx., and therefore $[H^{\cdot}] = 10^{-7}$, whence the *p*H corresponding to true neutrality is *circa* 7. Assuming hydrochloric acid to be completely ionized in a decinormal solution, then its *p*H would be 1, whereas for a decinormal solution of a completely ionized base $[OH'] = 10^{-1}$, whence $[H^{\cdot}] = 10^{-14}/10^{-1}$, and therefore its *p*H would be 13. Similarly the *p*H of a centinormal solution of an ionized acid is 2, whereas that of a centinormal solution of an ionized alkali is 12. Hence acidity and alkalinity can be considered in terms of a *p*H scale ranging from 0 to 14, with *p*H 7 marking the stage when acidity changes over to alkalinity, the criterion of acidity being that $[H^{\cdot}] > [OH']$ and of alkalinity that $[H^{\cdot}] < [OH']$. It should always be borne in mind that the *p*H scale is a logarithmic one, in which any *p*H value refers to a concentration of hydrogen-ions which is one tenth of the concentration indicated by a *p*H value 1 unit smaller.

The direct method of measuring the concentration (or activity) of hydrogen-ions is by means of the hydrogen electrode. Several other methods are available for *p*H determinations, but it must be emphasized that they all depend on the hydrogen electrode, for they have all been standardized by reference to it. These methods are: (i) *electrometric:* the quinhydrone electrode, metal-metal oxide electrodes (of which the most important is the antimony electrode), and the glass electrode; (ii) *colorimetric: without*, and *with*, the aid of standard buffer solutions.

The hydrogen electrode is of limited application as it cannot be used in the presence of many oxidizing agents, neither can it be used in solutions containing cations of metals more noble than hydrogen. Catalytic reduction can be minimized by using coarse platinum black deposits on the electrodes, such that the potentials first set up are those caused by equilibrium with the hydrogen-ions before the subsequent reduction effects have time to appear. This applies to dilute solutions of nitric and chromic acids and to blood. The quinhydrone suffers from these limitations to a much less extent, so much so that it can be used with unsaturated acids and in the presence of cupric ions. Its great drawback is that it cannot be used in alkaline solutions, i.e. with *p*H values greater than 7. The antimony electrode is finding increasing application, particularly in industrial processes and in medical research. Its potentials can easily be calibrated in terms of *p*H values, but as these potentials depend upon the age and nature of the oxide which is formed upon its surface, the electrode requires to be frequently standardized. Substances in solution, such as free acid or alkali or salts of hydroxy acids, tend to impair the antimonious oxide film and therefore to render the antimony electrode as a hydrogen-ion indicator somewhat erratic. Under ordinary conditions its

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

potential is approximately a linear function of *p*H from 1 to 11, and within smaller *p*H ranges it can be made to indicate readily *p*H values to within ± 0·05 *p*H unit, which accuracy is adequate for many industrial purposes.

Provided a suitable glass be employed, which should preferably be one of sodium calcium silicate (e.g. SiO_2 72 per cent., Na_2O 22 per cent., CaO 6 per cent.), glass electrodes can be prepared the potentials of which bear a definite relationship to those which would be established at a hydrogen electrode immersed in the same solutions up to a *p*H of 9·5. In solutions of higher *p*H values the electrode enters into equilibrium with both hydrogen-ions and sodium-ions, but if the glass electrode has been calibrated in solutions having the same sodium-ion concentrations as the solutions being tested, the electrode can be used up to a *p*H of 13 or even higher. The glass electrode consists of an exceedingly thin glass diaphragm which separates two aqueous solutions, one being a buffer solution of known *p*H and the other the solution undergoing test. Two difficulties, however, arise in using the electrode. The first is caused by the very high resistance of the glass membrane—several megohms—which imparts to the cell combination a very high internal resistance and thus makes the measurement of its E.M.F. a problem of some difficulty. By thoroughly insulating the copper wire lead from the glass electrode to the measuring unit and by employing thermionic valve amplification, the exceedingly small current through the glass cell can be magnified sufficiently to operate the usual measuring instruments such as millivoltmeters (which in turn can be made self-recording, figure 1), electric bells, etc. The second difficulty lies in a slight difference between the surfaces of the membrane. This might have been introduced during the blowing of the membrane or it may be produced by the chemical action of test solutions themselves, especially if they are of high *p*H (11–14) or low *p*H (1–3). This additional potential difference is the so-called *asymmetry E.M.F.* At first a glass electrode has generally a high asymmetry E.M.F., which gradually diminishes with use. Employment of the electrode in solutions of widely different *p*H may cause haphazard variations, but when it is used in solutions of similar *p*H the variations are usually negligible over a period of a day; moreover, the asymmetry E.M.F. remains sensibly constant throughout the complete *p*H range. This makes it possible to convert the E.M.F. of a glass cell, measured with a thermionic valve voltmeter, directly into *p*H values; a buffer solution of known *p*H is used in place of the test solution in the glass cell, and the *p*H scale attached to the voltmeter is adjusted so that the needle indicates that particular *p*H.

All the cells used for the electrometric determination of *p*H values involve the interposition of a saturated solution of potassium chloride between the hydrogen electrode, or its substitute, and the standard electrode, usually either the 'normal' or the 'saturated' calomel electrode. Because of the approximately equal ionic mobilities of the potassium and chloride ions, it is considered that such a solution will eliminate, or else reduce to a negligible amount, the potential difference which otherwise would be set up at the point where the two electrode solutions meet. The use of these liquid junctions renders the applicability of the G. N. Lewis 'activity theory' to this type of cell extremely dubious and uncertain. Hence *p*H values obtained from such cells cannot strictly be considered in terms of hydrogen-ion activities. Occasionally, workers select potentials for the standard electrodes which have been referred to the 'activity' standard hydrogen electrode, and which have been computed from the E.M.F.s of cells *without* liquid junctions. This is inconsistent. Most of the buffer solutions have been standardized with the hydrogen electrode in conjunction with a calomel electrode, the potential of which has been referred to the original arbitrary standard, viz. a hydrogen electrode, supplied with hydrogen at atmospheric pressure, immersed in a solution which, on the basis of the Arrhenius theory, was believed to contain 1 gram-ion of hydrogen-ions per litre. Although serious objections may be raised against the computation of ion concentrations from conductivity measurements, it seems desirable to retain this fundamental standard for the purpose of *p*H determinations if only for the sake of uniformity and consistency. Whatever may be the true meaning of *p*H values, they constitute an invaluable method of stating precisely the intensity of acidity or alkalinity.

Schematically (as a brief reference) the cells used are as shown overleaf ((2), (3), (4)).

Britton and Robinson found λ to increase progressively from + 0·263 volt to 0·302 volt as the *p*H is raised from 1·81 to 11·94. Over small *p*H ranges, e.g. 3 *p*H units, λ is sufficiently constant for the voltmeter used to be converted into a direct *p*H-reading instrument, when once the *p*H scale has been adjusted by testing the antimony electrode in a solution of known *p*H.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

(1) *Hydrogen:* $\overset{+}{Hg} \mid Hg_2Cl_2 \cdot KCl_{(c)} \mid$ Satd. KCl $\mid$ Test soln. $\mid \bar{H}_{2Pt}$

$$E.M.F. = E_{Calomel} + 0{\cdot}000198{\cdot}4 \times T \times pH$$

(2) *Quinhydrone:* $\overset{+}{Pt} \mid$ Test soln. + Quinhydrone $\mid$ Satd. KCl $\mid KCl \cdot Hg_2Cl_{2\,(c)} \mid \bar{Hg}$

$$E.M.F. = 0{\cdot}7175 - 0{\cdot}00074 \times t^\circ - 0{\cdot}0001984 \times T \times pH - E_{Calomel}$$
(t° = ° Centigrade; T = ° absolute)

(3) *Antimony:* $\overset{+}{Hg} \mid Hg_2Cl_2 \cdot KCl_{c} \mid$ Satd. KCl $\mid$ Test soln. $Sb_2O_3 \mid \bar{Sb}$

$$E.M.F. = E_{Calomel} - \lambda + 0{\cdot}0001984 \times T \times pH$$

(4) *Glass* $\overset{+}{\text{Soln. of known } pH\ (pH_K)} \mid$ Thin glass membrane $\mid \bar{\text{Test soln. } (pH_T)}$

(i) Hg | Hg_2Cl_2·N KCl | Satd. KCl | Soln. of known pH_K | Glass | Test soln. pH | Satd. KCl | N·KCl·Hg_2Cl_2 | Hg

(ii) Hg | Hg_2Cl_2·0·1N·HCl | Glass | Test soln. | Satd. KCl | N·KCl·Hg_2Cl_2 | Hg

(iii) Ag | AgCl·0·1N·HCl | Glass | Test soln. | Satd. KCl | N·KCl·Hg_2Cl_2 | Hg

(iv) Pt | *Quinhydrone:* 0·1N·HCl | Glass | Test soln. | Satd. KCl | N·KCl·Hg_2Cl_2 | Hg

The actual magnitude of λ is determined by the actual, though exceedingly small, solubility of the Sb_2O_3, present on the surface of the electrode, in the solution undergoing test; and this is influenced by the size, the age, and the treatment of the oxide layer. Frequent standardization of the electrode will therefore be necessary. The polarity of the cell is as shown above, (4), when $pH_T > pH_K$, whence E.M.F. = 0·0001984 T ($pH_T - pH_K$) + $E_{Asymmetry}$. Unfortunately the E.M.F. between two solutions cannot be directly measured, and therefore electrical contact with the two solutions is made by means of electrodes having fixed potentials, as shown above, (i), (ii), (iii), (iv). In combination (i) the two calomel electrodes equally oppose one another, whereas in (ii), (iii) and (iv) the left-hand electrodes establish constant potentials both at the terminal metal electrodes and at the left side of the glass membrane. The E.M.F. of a glass cell combination is therefore equal to the E.M.F. given by the foregoing expression *plus* a fixed E.M.F. equal to the difference between the potentials of the two auxiliary terminal electrodes (= E_{Fixed}).

Hence: $E.M.F. = E_{Fixed} + E_{Asymmetry} \pm 0{\cdot}0001984 \times T \times (pH_T - pH_K)$

APPLICATIONS

To illustrate a few of the possibilities of these pH electrometric methods in studying chemical reactions, reference will now be made to some work which has been carried out by the author and his research students.

Metallic hydroxides, or more generally basic salts, are each precipitated within narrow pH ranges characteristic of the particular hydroxides (cf. Table). The concentration of the metallic

HYDROXIDE PRECIPITATION pH FROM DILUTE SOLUTIONS

$Mg^{..}$	pH 10·5	..	$Be^{..}$	pH 5·7
$Mn^{..}$	8·5–8·8	..	$Fe^{..}$	5·5
$La^{...}$	8·4	..	$Cu^{..}$	5·3
$Ag^{.}$	7·5–8·0	..	$Cr^{...}$	5·3
$Ce^{...}$	7·4	..	$UO_2^{..}$	4·2
$HgCl_2$	7·3	..	$Al^{...}$	4·1
$Pr^{...}$	7·1	..	$Hg_2^{..}$	3
$Nd^{...}$	7·0	..	$Th^{....}$	3·5
$Zn^{..}$	7·0	..	$In^{...}$	3·4
$Sa^{...}$	6·8	..	$Ce^{....}$	2·7
$Co^{..}$	6·8	..	$Hg(NO_3)_2$	2
$Y^{...}$	6·8	..	$Sn^{....}$	2
$CdSO_4$	6·7	..	$Sn^{..}$	2
$Ni^{..}$	6·7	..	$Zr^{....}$	2
$Pb^{..}$	6·0	..	$Fe^{...}$	2

salt solution from which precipitation occurs has a small effect on the pH of precipitation. Anions, however, have but little effect, except in the case of bivalent mercury and cadmium. Basic carbonates, chromates, borates, etc., precipitate at the respective metal 'hydroxide pH' when the various metal salt solutions are treated with the alkali salts of the corresponding weak acid. To precipitate normal carbonates and chromates of heavy metals the solubility product requirements must be satisfied in the mother-liquor at a pH lower than the 'hydroxide pH,' or a basic salt will separate.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

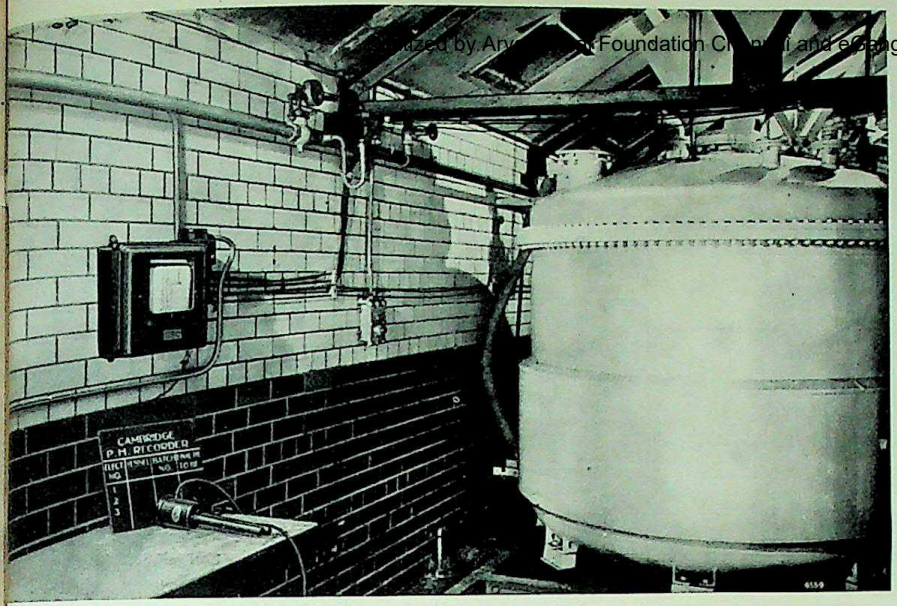


FIGURE 1 – *Cambridge automatic pH recorder, fitted to tanks used in the manufacture of fine chemicals. The electrodes of the 'dip-type system' (figure 2) are seen on the left.*
(By courtesy of the Cambridge Instrument Company Limited.)

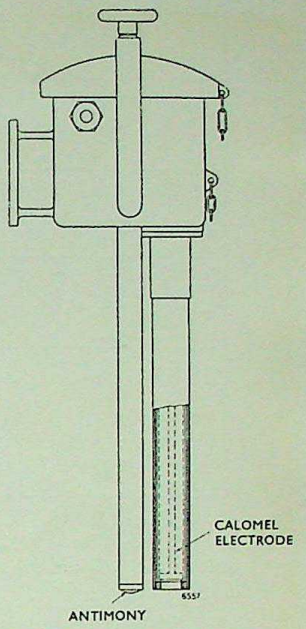


FIGURE 2 – *Cambridge dip-type electrode system specially designed for industrial work. One limb consists of an insulated tube carrying a plug of antimony; the other carries a calomel electrode.*
(By courtesy of the Cambridge Instrument Company Limited.)

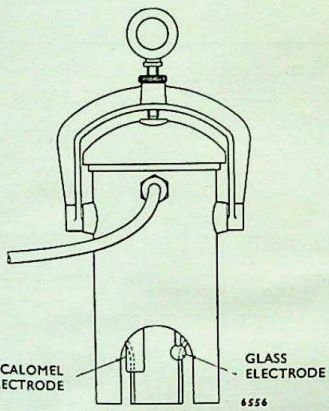


FIGURE 3 – *Cambridge submersible electrode system. The electrodes are contained in a cylindrical body of rubberized metal cut away so as to allow free access of the liquid. The electrodes may be either glass-calomel or antimony-calomel.*
(By courtesy of the Cambridge Instrument Company Limited.)

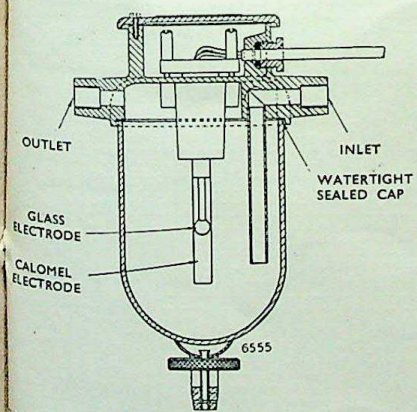


FIGURE 4 – *Cambridge continuous-flow electrode system, which is fitted directly into the pipe-line. The electrodes may be either glass and calomel or antimony and calomel.*
(By courtesy of the Cambridge Instrument Company Limited.)

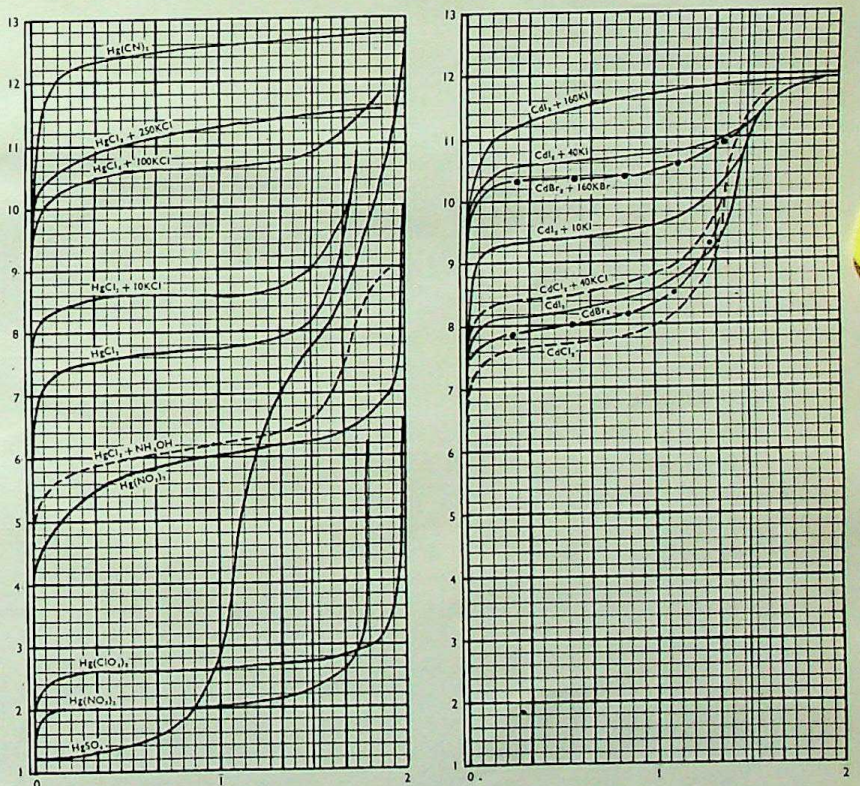
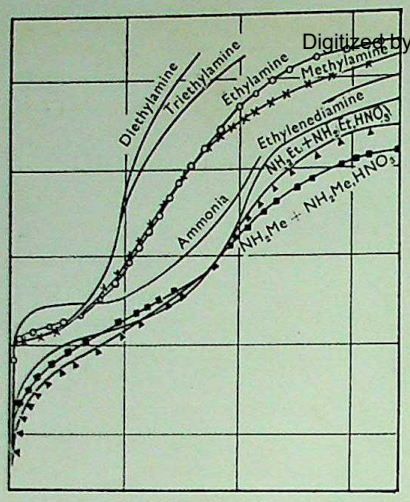


FIGURE 5 – *pH curves illustrating precipitation from mercuric and cadmium salt solutions.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

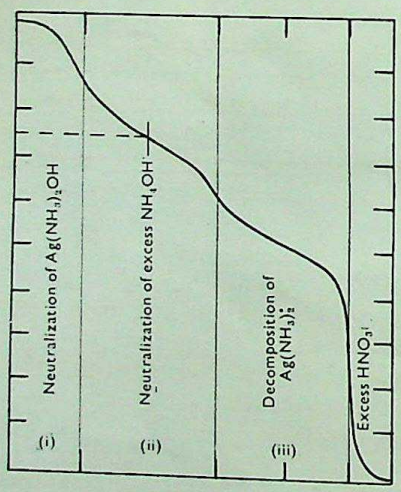
Digitized by Arya Samaj Foundation Chennai and eGangotri



Britton and Wilson, *J. Chem. Soc.*, 1933, 1050; Britton and Williams, *ibid.*, 1936, 96.

FIGURE 6 – p*H changes during addition of* NH_4OH *and substituted ammonias to silver nitrate solution, which show the formation of the complex salts:*

$Ag(NH_3)_2NO_3$, $Ag(CH_3NH_2)_2NO_3$,; $Ag(C_2H_5NH_2)_2NO_3$; $AgC_2H_4(NH_2)_2NO_3$.



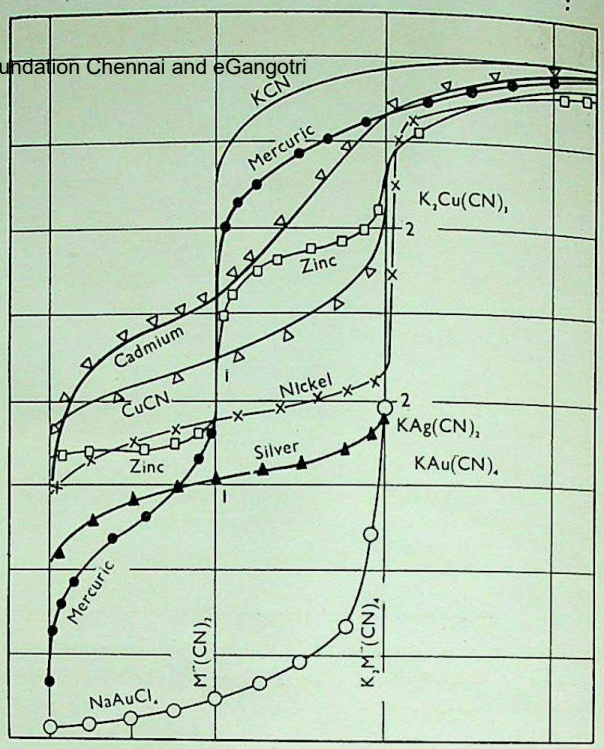
Britton and Wilson, *J. Chem. Soc.*, 1933, 1050; Britton and Williams, *ibid.*, 1935, 796.

FIGURE 7 – p*H neutralization curve of an ammoniacal solution of silver oxide showing the three separate stages represented by the equations:*

(*i*) $Ag(NH_3)_2OH + HNO_3 \rightarrow Ag(NH_3)_2NO_3$.

(*ii*) $NH_4OH + HNO_3 \rightarrow NH_4NO_3$.

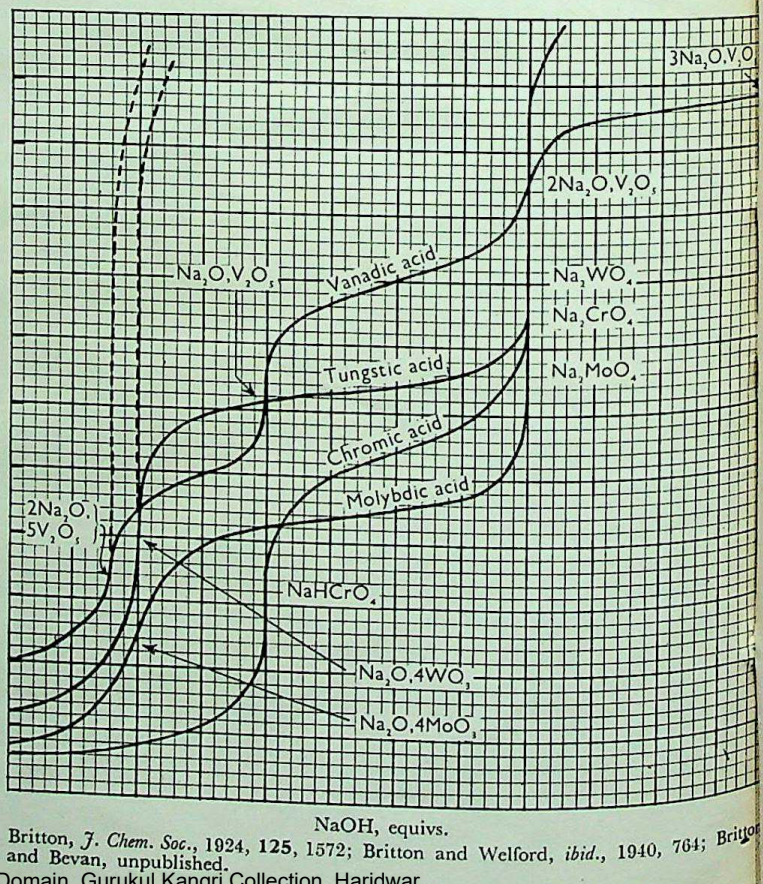
(*iii*) $Ag(NH_3)_2NO_3 + 2HNO_3 \rightarrow AgNO_3 + 2NH_4NO_3$.



KCN, mols.

Britton and Dodd, *J. Chem. Soc.*, 1932, 1940; *ibid.*, 1935, 100.

FIGURE 8 – p*H curves showing the formation of complex cyanides. (The curve marked* KCN *gives the* p*H values which would have been set up if only the cyanides of the metals had been formed.)*



NaOH, equivs.

Britton, *J. Chem. Soc.*, 1924, **125**, 1572; Britton and Welford, *ibid.*, 1940, 764; Britton and Bevan, unpublished.

FIGURE 9 (*right*) – p*H neutralization curves showing* (1) *that chromic acid is a normal dibasic acid;* (2) *the abnormal features of molybdic, tungstic, and vanadic acids.*

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

That metal hydroxides precipitate at characteristic *p*H values makes their separation possible either by adding alkali and controlling the *p*H, found by direct measurement, or by including in the solution a buffer system that will prevent the attainment of a particular 'hydroxide *p*H' on adding alkali and so prevent the precipitation of that hydroxide.

Figure 5 gives some *p*H precipitation curves of mercuric oxide and cadmium hydroxide—the horizontal sections before the inflexion representing the *p*H during the course of precipitation. Mercuric oxide is a very weak base and the sulphate, nitrate, and perchlorate are strongly hydrolysed and ionized. The consequence is that mercuric oxide is precipitated below *p*H 3. Mercuric nitrite, acetate, chloride, bromide, and cyanide are, however, almost unhydrolysed and un-ionized in solution. This is reflected in the *p*H at which alkali causes precipitation, e.g. from the chloride between *p*H 7 and 8, and only in extremely alkaline solutions from the cyanide. Incidentally, these salts form complex salts of the type K_2HgR_4 when the corresponding potassium salts are present in the solution. The curves marked 10, 100, and 250 KCl show the effect which these increasing amounts have on the *p*H of precipitation when added to mercuric chloride in the ratios indicated. By employing large amounts precipitation may be entirely prevented. This explains why mercuric oxide dissolves in potassium chloride, bromide, or iodide solutions with the liberation of an equivalent amount of alkali, thus:

$$H_2O + HgO + 4KI \rightarrow K_2HgI_4 + 2KOH$$

Figure 5 (*right*) shows that similar effects are produced with cadmium chloride, bromide, and iodide.

The broken line in figure 5 (*left*) refers to the addition of ammonia to mercuric chloride. Precipitation occurred at about *p*H 6, which is lower than when alkali was added. Both precipitates were mainly $3HgO,HgCl_2$, but the ammonia precipitate contained, in addition, co-ordinated NH_3, thus: $3HgO,HgCl_2,2NH_3$. These white ammoniated precipitates have the general formula $xHgO,HgCl_2,2NH_3$, and as such are basic salts which are related to 'fusible white precipitate,' $HgCl_2,2NH_3$, which is precipitated when ammonia is added to a solution of mercuric chloride and a large amount of ammonium chloride—the effect of the latter being to repress the ionization of the precipitant and at the same time to form $(NH_4)_2HgCl_4$, so that only the insoluble co-ordinated compound is precipitated.

Figure 6 illustrates the formation of co-ordinated silver salts when ammonia and substituted ammonias are progressively added to silver nitrate; in some cases, the nitrate of the free base was included in the solution to repress the ionization of the added base. Many curves, in being inflected when two equivalents of base, (B), were added, show that the salts $Ag(B_2)NO_3$ must have been formed. These salts are those of strong bases, $AgB_2OH \rightleftharpoons AgB_2^{\cdot} + OH'$, and this can be shown by titration with nitric acid of solutions of the organic bases in which silver oxide has been dissolved. The *p*H curve of such a titration is given in figure 7, the first section of which corresponds to the neutralization of $Ag(NH_3)_2OH$ and shows that the base is comparable in strength with that of alkali.

Complex cyanide formation is indicated by several of the curves in figure 8, which refer to the addition of potassium cyanide to metal salt solutions, except the one marked CuCN, which refers to a suspension of cuprous cyanide. The final inflexions show that $KAu(CN)_4$, $KAg(CN)_2$, $K_2Cu(CN)_3$, $K_2Ni(CN)_4$, and $K_2Zn(CN)_4$ are formed.

The neutralization curves of the acids shown in figure 9 show that (1) chromic acid is a normal dibasic acid, the first inflexion marking the formation of $NaHCrO_4$ (not $Na_2Cr_2O_7$), and the second of Na_2CrO_4; (2) tungstic and molybdic acids are abnormal, in that their first stages corresponding to the neutralization of strong acids terminate with 0·5 equivalent of an acid, i.e. when $Na_2O,(MoO_3)_4$ and $Na_2O,(WO_3)_4$ are respectively formed. The broken line shows the immediate effect of alkali on the tetratungstate, which is decomposed only after prolonged standing, or on boiling after each addition of alkali, when it is converted into Na_2WO_4 as shown by the curve. The tetramolybdate is converted by alkali immediately into Na_2MoO_4; (3) vanadic acid is initially abnormal. The neutralization of its strong acid stage terminates with the formation of $2Na_2O,5V_2O_5$, which salt is not readily decomposed by the further addition of alkali (hence the broken line in figure 9) except slowly on standing or rapidly on boiling, when the *p*H is shown by the neutralization curve, and the acid then becomes comparable with phosphoric acid in forming the salts Na_2O,V_2O_5 or NaH_2VO_4 and $2Na_2O,V_2O_5$ or Na_2HVO_4.

Electrometric *p*H methods have also been used in several other investigations, many of which await publication.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The Chinese beginnings of alchemy

TENNEY L. DAVIS

It is sometimes stated that alchemy is the parent of chemistry, but in fact alchemy—the attempt to discover an elixir of life and the philosopher's stone—presupposes the accumulation of much chemical knowledge. Professor Davis discusses early Chinese alchemy and suggests that occidental adepts received much of their lore from China by way of India and Islam. The oldest known treatise on alchemy (about A.D. 120) is Chinese.

The beginnings of chemistry are so remote that it is impossible to assign a date to them. They lie in the time which preceded the age of fable and mythology, in that vague and lengthy age during which giants and legendary heroes had not yet appeared, and the pagan gods had not yet discovered their proper ranks and offices. Chemists were already practising their art before the strong god Thor had received his hammer or had hurled his first thunderbolt. Wishing for a weapon, Thor had applied to the dwarfs, to the little metallurgical chemists who stoked their fires under the earth, and had asked them to make him one. Then impatiently he pestered them, until they removed the hammer too soon from the furnace, excellent in all respects except that its handle was unduly short. With a short-handled hammer he accordingly fulfilled his godly functions. When he shook it about his head, the thunder rolled. When he threw it at an object, the object was struck by lightning. Tubal-cain, seven generations removed from Adam, was likewise a chemist, as was his Graeco-Roman counterpart, Hephaistos–Vulcan, who tended his forges under Etna. For the present purpose it is enough to note that no date can be assigned to Tubal-cain or to the dwarfs who worked for Thor, and it is enough to believe that these early chemists, observing the changes which occurred in their processes, undoubtedly had theories—chemical theories—to account for them.

The case is different with alchemy. The term 'alchemy' is understood to signify the search or the effort, whether successful or not, by chemical means to prepare a medicine of longevity or of immortality, or by chemical means to prepare authentic noble metal from base metal—either or both of these pursuits. It follows that alchemy is not as ancient as chemistry, that alchemy arose after the chemical means for its practice had already been developed. Evidently, too, it arose at a time when chemistry has accomplished such marvels that the objectives of alchemy seemed not so extravagant as to be beyond hope of attainment.

Alchemy first made its appearance in such manner that its relation to magic was demonstrated clearly. Gold was wanted because of its magical property of conferring immortality by eating it or by eating out of vessels which were made from it, and chemistry was called upon to make the gold. Chemistry became alchemy when it served for this purpose, and chemical theory, invoked for the explanation of the gold-maker's art, became the theory of alchemy.

The earliest known case of indubitable alchemy is mentioned in the *Shih Chi* [Historical Memoirs] which was commenced by Ssŭ-Ma T'an and completed by his son, Ssŭ-Ma Ch'ien (145-87 B.C.), who succeeded him as grand astrologer and grand annalist to the Chinese court. This work deals with the history of China from the earliest times to 122 B.C. Chapter XXVII tells about Li Shao Chün, a magician and alchemist at the court of the Han Emperor, Wu Ti (156–87 B.C.), within the lifetime of the historian himself, who

> constantly affirmed that he was 70 years of age, that he was able to rule over spiritual matters, and that he could escape old age. . . . He travelled about in order that reports of his prowess might reach the ears of nobility. . . . He excelled in showing himself shrewd, and in saying things at the same time astounding and accurate.

He proclaimed his powers as follows:

> 'I know how cinnabar transforms its nature and passes into yellow gold. I can rein the flying dragon and visit the extremities of the earth. I can bestride the hoary crane and soar above the nine degrees of heaven.'

He offered instruction to the Emperor:

> 'If you will make sacrifice to the furnace, you will be able to transmute cinnabar into gold. When the gold shall have been produced, you may make

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

of it utensils for eating and drinking. Through using them your life will be prolonged, so that you may see the blessed immortals of the island of P'êng-lai which lies in the midst of the ocean. When you shall have seen them, and shall have made proper sacrifice to high heaven and broad earth, then you will never die.'

The *Shih Chi* further records that

it was after this discourse that the Son of Heaven for the first time performed in person the sacrifice of the furnace. . . . He occupied himself in experimenting with powdered cinnabar, and all sorts of drugs, in order that he might obtain gold.

The Emperor engaged in chemical experimentation from an alchemical motive, hoping to benefit by the magical properties of his product.

An earlier case of what was probably alchemy, although the evidence is not quite so unequivocal, is described in Chapter VI of the *Shih Chi*, which tells of the three supernatural islands in the midst of the Eastern Sea, P'êng-lai, Fang-chung, and Ying-chou: 'It is there that the immortals may be found and the drug which prevents death.' The Ch'in Emperor, Shih Huang Ti (259–210 B.C., King of Ch'in from 246 B.C., Emperor of China from 221 B.C.), the same who established a new dynasty, built the Great Wall, and introduced the hair pencil or brush for writing on silk instead of on bamboo tablets, became interested in what he heard concerning the drug which prevents death. The magicians, Lu Shêng and Hsü Shih, otherwise Hsü Fu, influenced him to organize an elaborate naval expedition for the purpose of searching for them:

Hsü Shih and his companions tendered the following request: 'We make supplication that we be permitted, after we have purified ourselves, to depart with a company of youths and maidens to seek these islands.' . . . The Emperor was well pleased. He gave to Hsü Shih seeds of the five grains and dispatched him upon his voyage with three thousand young men and women, and labourers for all kinds of work. Hsü sailed away, and discovered a locality noted for its peace and fertility. There he tarried, was made king, and did not return.

The Emperor continued to hope for the return of the expedition:

It was his custom to promenade up and down the seashore in the hope that he might in some manner obtain the wonder-working drug of the three sacred islands in the midst of the sea, but he never obtained it. He returned to Sha Ch'iu, and there he died.

The expedition of Hsü Shih set out in the year 219 B.C., and, according to present belief, went to Japan, where it established a settlement near the site of the present city of Shingu, at the eastern end of Wakayama Prefecture, near the southernmost end of the Japanese main island. The grave of Hsü Shih (Joshi or Jofuku, as the Japanese call him) exists at that place and is today an object of reverence by pilgrims and others. Hsü Shih has the reputation of an alchemist, but it has not been definitely established that the medicine which he sought required a chemical preparation and that he was a worker with the processes of chemistry.

Liu An or Huai-nan-tzŭ (died 122 B.C.) was the grandson of the first Han Emperor, Kao Ti, and was created Prince of Huai-nan. He was a famous Taoist and is supposed to have been devoted to the study of alchemy and the search for the pill of immortality, on which subjects he is said to have written several treatises. Wei Po-yang, 'the father of alchemy,' mentions him twice in the *Ts'an T'ung Ch'i* (written about A.D. 142), and Ko Hung (A.D. 281–361), in his chapter on the Yellow and the White, the sixteenth of the Inner Chapters of Pao-p'u-tzŭ, mentions a work of Huai-nan-tzŭ which is not now known to exist, the *Chên Chung Hung Pao* [The Great Treasure in the Pillow Chest], and tells a story from it about a successful transmutation. The only existing writing which bears his name is the *Hung lieh* [Great Light, i.e. *Tao*], a collection of twenty-one essays, probably written by eight famous scholars whom he attracted to his court, or written in collaboration with them, and edited by Huai-nan-tzŭ himself. It is a treatise on cosmogony and ethics, on social problems, on man's place in nature, on the full life. It contains no alchemy, but it does set forth the dualistic *Yin-Yang* doctrine, which supplied a basis for Chinese alchemical theory, for an alchemical theory which was earlier than that of Europe and identical with it in all important respects.

The tradition that Liu An was an alchemist is illustrated by the fact that an account of him is included in the *Lieh Hsien Ch'üan chuan* [Complete Biographies of the Immortals], which tells how he prepared the medicine by chemical means and secured immortality, ascending directly to heaven, by the use of it. Actually he became involved in a political intrigue and, according to one account, was sent into exile; according to another he killed himself. The eight scholars who collaborated with him in his studies are represented in the *Lieh Hsien Ch'üan chuan* as eight

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

hsien (supernatural immortals), who came to his court for the purpose of instructing him concerning *Tao*. One of them, the last to speak in the passage quoted below, was obviously a chemist:

'We have heard that your Highness loves the *Tao*. So we have come to join your court. But we do not know what your Highness desires.

'One of us can cause winds and rain by sitting down, can raise clouds and fog by standing up, can make rivers and lakes by drawing on the ground, and can create mountains by piling of sand.

'One of us can crumble heights and fill up the deep, can husband the tiger and the leopard, can catch the dragon and the snake, and can master gods and ghosts.

'One of us can separate his form and change his appearance, can cause life by sitting down and death by standing up, can cover a complete army from sight, and can turn broad daylight into darkness.

'One of us can ride in space and walk on emptiness, can go into the sea and the deep, can go in and out through any partitions, and can breathe a breath of a thousand miles.

'One of us can go into the fire without being scorched, and into water without being wetted, can be stabbed without being hurt, can be aimed at but never hit by an arrow, and is not cold in freezing water, and does not sweat in summer.

'One of us can perform thousands of changes at will. He can bring forth birds and animals, weeds and woods in a moment. He can move mountains, heights, and rivers.

'One of us can prevent havocs, reclaim from dangers, dispel evils, and do away with harmful things. He can cause longevity.

'One of us can boil mud to get gold, assay lead to get silver, and treat the eight stones to give pearls. He can ride the dragon and harness the clouds to travel afloat on the Great Clearness.

'What does your Highness desire?'

Liu An made obeisance to the eight *hsien*. He offered wines and fruits to them with his own hands. The *hsien* were tested one after the other and were confirmed in their ability. He was given the Book of the Medicine, the Thirty-Six, and the mercury recipes. The medicine was made but was not taken.

Now Liu An had a son, of the name of Ch'ien, who loved fencing. One day Ch'ien fenced with an official and was hurt. The latter, fearing punishment, wrote to the Emperor alleging that Liu An was plotting revolt. The Emperor sent Tsung Chêng to bring Liu An to justice.

The eight *hsien* said to Liu An: 'You must go now. This is a heaven-sent messenger for you to depart. So harbour no doubt.' Liu An went with them up into the mountain. There they made a great ceremonial offering and buried the gold in the earth. They rose to the sky in broad daylight.

The stones on which the eight *hsien* and Liu An had stepped became marked. Even now they are found to have the footprints of men and of horses. Chickens which peck at the *tings* [furnace-pots, three-legged incense-burners] used in preparing the medicine, and dogs which lick them, attain lightness. The chickens will cackle and the dogs will bark in the sky.

The dualistic doctrine of Yin-Yang appeared in China during the third century B.C., and from that time to this has dominated a large part of Chinese thought on philosophical and scientific matters. Similar doctrines existed in other places at an earlier date, notably in India and in Mesopotamia, and it is possible that they may have been imported into China. In any case, it is interesting to find that the doctrine appears already elaborated, already supplied with an extensive and fantastic symbolism, at the moment when it first occurs in association with alchemy, in the earliest known treatise in any language which is devoted exclusively to that subject.

The earliest known treatise on alchemy is the *Ts'an T'ung Ch'i* [Akinness of the Trio] of Wei Po-yang. It has been preserved for us as part of the Taoist canon. Its author, about whom very little is known, was a native of Wu in the present province of Kiangsu. In the year A.D. 121 he was summoned to court, but refused the invitation because he had no liking for officialdom. An account of him, containing elements which are obviously mythical, is found in the *Lieh Hsien Ch'üan chuan*. In the Epilogue of the *Ts'an T'ung Ch'i* he describes himself as 'a lowly man from the country of Kuai who has no love for worldly power, glory, fame, or gains, who wastes his days leading a simple, quiet, leisurely, and peaceful life in a retreat in an unfrequented valley.'

Primitive science viewed all things as resulting from the combination or interaction of the Two Contrary Principles, one of them having all of the positive qualities, active, hot, dry, light, and spiritual; the other, all of the negative qualities, passive, cold, wet, heavy, and material. Since the Contraries were difficult to describe precisely, they were designated by names which had broad connotations; they were associated with deities, Osiris and Isis, Baal (or Bel), and Astarte (Ashtaroth or Ishtar), Shiva and Parvati; with the two regulating powers of the universe, one of them, *Yang*, the principle of activity, the other, *Yin*, the principle of material acted upon. They

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 1 – *Liu An, Prince of Huai-nan.*

Liu An and one of the *hsien* who taught him the art. The dog and the cock, having respectively licked and pecked at the vessels in which the medicine was made, also ascended into the sky.

(*Reproduced from the* Lieh Hsien Ch'üan chuan [*Complete Biographies of the Immortals*].)

FIGURE 2 – *The preparation of the pill of immortality according to Shang-yang-tzu.*

Yang is represented by the man, dragon, and fire; *Yin* by the woman, tiger, and water in the forms of clouds, rain, and hail. The tortoise and the serpent, symbolizing the material embodiments of *Yang* and *Yin*, further represent the combination of the Two Contraries.

(*Reproduced from the Ming edition of the* Chin Tan Ta Yao [*Essentials of the Gold Medicine*], *written by Shang-yang-tzu, otherwise Ch'ên Kuan-wu, during the Chih-shun reign of the Yuan dynasty* (A.D. 1330–33).)

were designated by names which are to be taken as symbols suggestive of all of the qualities which each of them possessed. In Europe and in China alike they were Sun and Moon, Man and Woman, Fire and Water, Hot and Cold, Volatile and Fixed. For the Alexandrian chemists, and for the later European chemists and alchemists, the metals were combinations of the positive Sulphur and the negative Mercury principles, gold being the perfect combination of the two, and the principles being bundles of qualities, not confounded with yellow brimstone and liquid quicksilver. For the Chinese alchemists, positive *Yang* was Lead (instead of Sulphur), Dragon, the Golden Crow; negative *Yin* was Mercury, Tiger, the Jade Rabbit, and so forth. The same Two Contraries were known as Phlogiston and Calx to the chemists of the eighteenth century.

The *Ts'an T'ung Ch'i* describes the preparation of the pill of immortality by the heating together of the Two Principles in a closed vessel from which no vapours can escape, at first gently and finally with a strong fire. The hermetically sealed vessel, which the later European alchemists

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

FIGURE 3 – *The Combination of the Two Principles for the Production of the Philosopher's Stone.*

The intent of this picture is strikingly similar to that of figure 2. The Sulphur principle is represented by the Sun, by the King, and by fire; the Mercury principle by the Moon, by the Queen, and by water. [Note that the clouds above the Queen are not radiant as are those above the King.]

FIGURE 4 – *An alchemist's laboratory according to Basil Valentine.*

Obviously a place for the combination of the two contrary principles.

(Reproduced from wood-cut in the third German edition [Hamburg, 1700] of Basil Valentine's collected chemical writings.)

denominated the 'Philosopher's Egg,' is described by Wei Po-yang:

> On the sides there is the walled enclosure, shaped like a *p'eng-hu* pot. Closed in all sides, its interior is made up of intercommunicating labyrinths. The protection is so complete as to turn back all that is devilish and undesirable, and the meandering passages take good care of emergencies.

The tortuous passages serve as reflux condensers for the return of volatile material. The Principles themselves are indicated by allegorical names.

> In order that the Treatise on Fire shall not have been in vain, I shall explain here in simple language. Like the moon lying on its back is the shape of the furnace and the pot. In it is heated the White Tiger. Mercury Sun is the flowing pearl and with it is the Blue Dragon. The east and west merge together, and so the *hun* and *p'o* control one another. . . . The Red Bird is the spirit of fire and dispenses victory or defeat with justice. With the ascendance of water comes the vanquishing of fire.

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

The process itself:

Treatment and mixing will bring about combination and rapid entrance to the scarlet portal. The escape must be firmly blocked. Below plays the dazzling flame, while the Dragon and Tiger keep up a sustained vociferation. The flame at the start should be weak, so as to be controllable, and should be made strong at the end. Close attention and careful watch should be given so as to regulate properly the heat and the cold. . . . The colour changes into a purple. Behold! the Returned Medicine is obtained. This is then made into pills. These are extremely efficacious, although their individual size is so small that they occupy only the point of a knife or the edge of a spatula.

Wei Po-yang describes the appearance of the materials in language which indicates that he had observed chemical phenomena and had been profoundly impressed by them. There can be no doubt that the following passage is a description of a violent reaction accompanied by colour changes and the production of a sublimate:

Above, cooking and distillation take place in the cauldron; below blazes the roaring fire. Afore goes the White Tiger leading the way; following comes the Grey Dragon. The fluttering Scarlet Bird flies the five colours. Encountering ensnaring nets, it is helplessly and immovably pressed down and cries with pathos like a child after its mother. Willy-nilly it is put into the cauldron of hot fluid to the detriment of its feathers. Before half of the time has passed, Dragons appear with rapidity and in great number. The five dazzling colours change incessantly. Turbulently boils the fluid in the furnace. One after another they appear to form an array as irregular as a dog's teeth. Stalagmites, which are like midwinter icicles, are spit out horizontally and vertically. Rocky heights of no apparent regularity make their appearance, supporting one another. When *Yin* and *Yang* are properly matched, tranquillity prevails.

It is difficult not to believe in the continuity of alchemical thought when we find the same process described in the *Speculum alchemiae* which is ascribed to Roger Bacon, a treatise written more than a thousand years later than the *Ts'an T'ung Ch'i:*

Another says: 'This work is similar in many respects to the creation of man, for, as a child is nourished at first with lighter foods until the bones are formed, then with stronger ones, so this magistery requires a slow fire by which it is acted upon in the manner of a decoction.' And always when we speak of a slow fire, we mean that the fire is to be augmented and made stronger gradually and in successive stages during the course of the work. . . .

If, then, we intend to imitate nature, we must necessarily have a furnace of the same sort, after the fashion of a mountain, not in size, but of such sort as to provide a continuous heat so that the fire imposed upon it shall not find an exit when it ascends and so that the heat shall reverberate the tightly closed vessel which contains within itself the material of the Stone. . . .

And as in the mines the heat does not touch directly the substance of the Sulphur and of the Quicksilver, because the earth of the mountain is everywhere between, so the fire ought not to touch directly the vessel which contains the above-mentioned materials. But this vessel must be placed within another vessel similarly closed, so that a temperate heat may better and more aptly reach the material above and below and from whatever side it may be.

Persons who ate the pill of immortality became *hsien*, supernatural immortals, for ever young, able to travel great distances, to pass through fire without being burned, through water without being wetted, able to change their form, to appear and to disappear at will. The powers of a *hsien* were the powers of a *jinn* as described in *The Arabian Nights Entertainments*, suggesting that the Arabic word may perhaps be derived from the Chinese and indicating a possible line of transmission whereby alchemy came from China to Europe.

The Latins received their alchemy from the Arab writers, who, though they may perhaps have received some of their chemistry from the Alexandrians, certainly received no alchemy from that source—for the Alexandrians had no alchemy to transmit. The Alexandrians had a dualistic chemical theory; they were interested in colour, and they applied their chemistry among various ways to the imitation of the noble metals. But they knew full well that their yellow and white metals were not genuine gold and silver. The Arabs had chemistry and they understood the art of colouring the metals; but they also had real alchemy, which they probably received from China, and they hoped to prepare authentic gold and silver by chemical means.

The truly alchemical character of Ko Hung's teaching is evident from the following remarkable passages, quoted from his chapter on the Yellow and the White, which show that he understood the art of imitating the metals and distinguished it clearly from genuine transmutation:

It is another story with the *chên jên* [men of truth, men proficient in the art, sages]. For they make gold with the purpose, not of getting rich, but of

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

becoming *hsien* by eating it. Therefore it is written in the book: 'Gold can be made wherewith people can be raised above this worldly life.' Silver may be eaten for similar ends but is not as effective as gold.

Then I asked further: 'Why should we not eat the gold and silver which are already in existence instead of taking the trouble to make them? What are made will not be real gold and silver but just make-believes.'

Said Chêng Chün in reply: 'The gold and silver which are found in the world are suitable for the purpose. But *Tao-shih* [seekers of the Way] are all poor; witness the adage that *hsien* are never stout and *Tao-shih* never rich. *Tao-shih* usually go in groups of five or ten, counting the teacher and his disciples. Poor as they are, how can they be expected to get the necessary gold and silver? Furthermore, they cannot cover the great distances to gather the gold and silver which occur in nature. The only thing left for them to do is to make the metals themselves.

'In that they are the essences of the medicines, the gold and silver made are superior to those found in nature. . . .

'The gold obtained by successful compounding is uniform inside and out. It may be put through a hundred workings without suffering any change. Therefore it is written in the formulas for its making that it may be made into nails. That shows its strength. Such results come of responsive infusion of the *Tao* of nature. Why should such deeds be called make-believes?

'Make-believes should be like the besmearing of iron with *ts'êng ch'ing* [malachite], whereby the metal takes on a reddish sheen simulating copper, and the action of egg-white on silver to obtain a yellow colouring resembling gold. In all these cases there are merely external changes but no internal transmutations.

'The fungus *chih* [plant of longevity] is a natural growth. But according to the *Hsien Ching* [Book of Immortals] it may be cultivated by means of the five stones and the five plants. The resulting plant will be exactly like that found in nature in the power of giving long life when eaten. The case is similar to the making of gold[1].

[1]While the translations quoted in the present paper are due mainly to the late Wu Lu-ch'iang, many of the facts and conclusions are due to my other Chinese collaborators or to discussions with them. This paper, embodying material from several earlier ones, would not have been possible without the past collaboration of Ou Chia-wei, Ma Chuk-ching, Su Gouq-jen, Chao Yün-ts'ung, and Ch'ên Kuo-fu. T.L.D.

Book reviews

ORGANIC CHEMISTRY

Theoretical Organic Chemistry, *by J. B. Cohen. Revised edition by P. C. Austin. Pp. xv + 622. Macmillan & Co. Limited, London.* 1942. 10*s. net.*

The fundamental character of developments in organic chemistry arising from the growth of modern electronic theory necessitates very extensive revision of any older textbook if a really modern work is to result.

In this revised edition of the late Professor Cohen's well-known book the general plan and text of the original have been very largely preserved. A new chapter on stereochemistry has been added, the sections on carbohydrates and proteins have been modernized, and heterocyclic compounds, alkaloids, ureides, and compounds of biological importance have been grouped together into a third, new, section. Such revision is adequate, but it is unfortunate that equal thoroughness is not evident throughout. Thus, as examples, although a short chapter outlining the electronic character of covalent, electrovalent, and co-ordinate links has been included, formulae containing quinquecovalent nitrogen are generally unchanged. Obsolete potash bulbs are still the only absorbent given for carbon dioxide in analysis. Claisen's original mechanism for the Claisen condensation (p. 328) and Fittig's for the Perkin reaction (p. 501), both now completely discredited, are reproduced unchanged. Diamines, choline, neurine, and taurine have, with advantage, been transferred to Chapter XIV on Amines, but still appear in Chapter XIX (Polyhydric Alcohols) in the unrevised Contents page xi. The statement that 'no completely satisfactory solution has yet been found' for the structure of benzene (p. 383) and for orientation rules in benzene substitution (p. 483) hardly gives the student a fair picture of the success of the resonance theory in interpreting the chemical and spectroscopic properties of benzene, or of electronic theories in the interpretation of aromatic substitution.

Notwithstanding such deficiencies, its amazingly comprehensive factual content makes the textbook a most valuable one for students and exceedingly good value at the price charged. J.W.B.

VITAMIN CHEMISTRY

Chemistry and Physiology of the Vitamins, *by H. R. Rosenberg. Pp. xx + 675. Interscience Publishers Inc., New York; Imperia Book Company Limited, London.* 1942. $12.00.

This book is outstanding in that it covers the field of chemistry and biochemistry of vitamins exceptionally well and ably describes the remarkable advances achieved in this connection during the past twenty years. The physiological aspect of the subject, which demands a wide knowledge of physiology, pathology, and medicine, is not, however, so well treated. This is a pity, since physiological investigations on vitamins have had a greater influence on the subject of physiology

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

than the parallel chemical investigations have had on pure chemistry. Whereas chemical and biochemical discoveries are fully surveyed, biological discoveries, even of a revolutionary nature, are often mentioned only casually, with little or no appreciation of their significance. Occasionally important and unimportant facts and claims are confused. This lack of critical appreciation detracts from the book's value to physiologists and may be misleading to those whose acquaintance with the subject is limited.

The book is very well produced and contains useful (although on the physiological side non-selective) indexes, including a patents index. From an educational standpoint, and for purposes of reference to the chemical aspect of vitamin research, it deserves the highest praise and recommendation. It might, however, be suggested that in the next edition the author should change the title to 'The Chemistry and Biochemistry of Vitamins.'

RECENT WORK ON COLLOIDS

Advances in Colloid Science, *edited by E. O. Kraemer, F. E. Bartell, and S. S. Kistler. Pp. xii + 434. Interscience Publishers Inc., New York; Imperia Book Company Limited, London*, 1942. 33*s. net.*

This volume contains twelve articles, most of them by first-rate experts, on many topics of current interest; only some can be mentioned here. T. F. Anderson describes the theory and many applications of the electron microscope very clearly, and gives many excellent photographs. R. J. Myers gives an excellent account of the interchange of ions between aqueous solutions and synthetic resins of carefully chosen constitution, on which an important new process for water purification is based. Emmett reviews in detail the way in which the amount of gas adsorbed depends on pressure, in cases where fairly large amounts are adsorbed, largely, if not entirely, by van der Waals forces, and convincingly works out a method for determining when the adsorbed layer is one molecule thick. From this, the total surface of the solid can be deduced. McBain collects a number of not very well known facts bearing on the way in which aqueous solutions of colloids, such as soap or similar substances, dissolve quite large quantities of substances which have very slight solubility in water alone, and discusses their importance for detergent action and for the permeability of membranes. Edsall's article on double refraction in solutions of minute, elongated particles, developed only when the solution flows under conditions involving shear, is masterly; so is Kurt Meyer's on starch. Powell and Eyring's treatment of viscosity, diffusion, and some other properties of solutions of large molecules is somewhat speculative, but full of new and stimulating ideas. Hauser gives a new method, based on measurement of the shape of hanging drops, for finding surface tension; but his discussion of 'anomalies' in surface tension is rather misleading, for he falls into the rather common error of trying to fit the simplified form of Gibbs' adsorption equation, which is really applicable only to two-component systems, to data obtained on solutions which must have at least three components where surface equilibria are involved.

This volume is indispensable to serious students of colloidal materials and should be in every library dealing with physical chemistry. It is all interesting, and most of it is of great importance. N. K. ADAM

THE THEORY OF VOLUMETRIC ANALYSIS

Volumetric Analysis, *by I. M. Kolthoff and V. A. Stenger.* Volume I: Theoretical Principles. *Pp. xv + 309. Interscience Publishers Inc., New York; Imperia Book Company Limited, London. Second revised edition.* 1942. 30*s. net.*

The first edition of this work, published in German in 1927 and translated into English by Professor N. H. Furman in 1928, filled an important gap in the literature of volumetric analysis and stimulated a greater interest in the study of the theory of the subject. This has been reflected in the space devoted to theoretical principles in a number of well-known and reasonably priced textbooks of quantitative inorganic analysis, including that of Kolthoff and Sandell (1936). About half the matter in the book under review is adequately covered by these textbooks, and it would appear to be an open question whether the remaining subject-matter justifies the publication of an independent volume at a price which is very high. In the reviewer's opinion, it would have been far better to combine Volume I with the promised new edition of Volume II (dealing with the practical side).

The book appears to be somewhat unbalanced. Thus in the chapter on indicators ten pages are devoted to acid-base indicators, but neither their structures nor the theories of the colour changes are discussed; on the other hand, thirty-five pages, including many detailed structural formulae, are given to oxidation-reduction indicators. The treatment is in some cases not always up to date, particularly in the otherwise interesting chapter on volumetric methods of organic analysis; here the reactions of unsaturated compounds are discussed from the viewpoint of Thiele's partial valency theory.

In spite of the above criticisms, the volume contains much of value to those interested in volumetric methods of analysis. Many references to the literature are provided. A. I. VOGEL

A DICTIONARY OF SCIENTIFIC TERMS

A Dictionary of Science, *by E. B. Uvarov, B.Sc. Penguin Books Limited, London and New York.* 1943. 9*d. net.*

This dictionary, compiled by a competent scientific lecturer, has been specially designed to help all those studying, or interested in, science. The majority of its definitions apply to physics, chemistry, and mathematics; the many cross-references will prove most helpful to readers. The suggestion might be ventured that in a later edition certain terms, for instance alembic, alkahest, astrolabe, and phlogiston, should give way to modern ones such as electron-volt, photoelectron, the Compton and Raman effects, etc. This, however, is a minor point and purchasers of this compact little volume will find they have got excellent value for their money.

C. M. BEADNELL

A TEXTBOOK FOR ENGINEERS

Modern Engineering, *by C. H. S. Tupholme. Pp. xi + 201. Faber and Faber Limited, London.* 1942. 15*s. net.*

The author of this book attacked a very wide subject in a definite manner and has achieved considerable success. Modern engineering is linked so closely with other sciences, such as physics and chemistry, and recent progress has been so rapid, that exhaustive treatment became neither possible nor desirable in a book such as the one under review. Accordingly, the author adopted the

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

method of presenting details of various important developments which have proved commercially successful. He has not attempted theoretical discussion, but has borne in mind the needs of younger men about to embark upon an engineering career, although the book is by no means limited to such requirements.

It is generally recognized that wartime conditions accelerate the rate of scientific and technical advance, while attempts at self-sufficiency stimulate inventive effort, and this viewpoint has been emphasized by Mr Tupholme; for example, if one turns to the question of mechanical power, details of the Velox steam generator, the Sulzer monotube boiler and the mercury vapour system will be found. In the case of engineering workshop processes there are excellent descriptions and explanations of many and diverse methods by which accuracy within very fine limits is obtainable.

The chapters on air-conditioning, refrigeration, chemical engineering, metallurgy, electrical and marine engineering, and traction are equally well treated. The section on aircraft will undoubtedly have a great appeal because in it many of the latest developments are dealt with, while the concluding chapter consists of brief descriptions of some recent advances in physics.

Particular mention must be made of the very excellent illustrations, twenty-three of which are full-page half-tone plates. The book is well written and produced and should have a wide appeal.

ARTHUR MARSDEN

X-RAY INVESTIGATION OF TEXTILES

Textile Fibres under the X-rays, *by W. T. Astbury. Pp.* 53, *with* 34 *figures. Imperial Chemical Industries Limited, London.* 1942. *N.p.*

This book is an album of X-ray diffraction photographs of textile fibres, with notes on each photograph, and an introduction describing the apparatus used in taking the photographs and the conclusions which can be drawn from them. Great care has been taken to display Astbury's excellent photographs to the best advantage, and the result is very pleasing to the eye as well as uncommonly informative. The text, written in a very attractive style (Astbury is a master of simple exposition), tells the layman what X-ray analysis is all about, and gives a bird's-eye view of the contributions it has made to our knowledge of the molecular structure of textile fibres.

C. W. BUNN

INDUSTRIAL TYPES OF CATHODE RAY OSCILLOGRAPHS

The Cathode Ray Oscillograph in Industry, *by W. Wilson. Pp. xii* + 150. *Chapman & Hall Limited, London.* 1943. 12*s.* 6*d.* net.

This entirely practical and very useful book is well designed to meet the great and growing demand for detailed information on industrial types of cathode ray oscillographs, both glass and metal. As it is intended for the actual user rather than for the academic reader, historical matter and mathematical treatment are almost entirely omitted to provide the maximum space for descriptions of apparatus and components, practical tests, and industrial applications. Television tubes are excluded, but electron diffraction apparatus and the electron microscope are described, and an appendix deals briefly with thermionic valves, photo cells, oscillators, and piezo crystals. Many well-reproduced photographs of apparatus and components and of oscillograms are included, as well as electrical circuit and other line diagrams.

W. J.

THE ESSENTIALS OF ENTOMOLOGY

Outlines of Entomology, *by A. D. Imms. Pp. viii* + 184, *with* 96 *illustrations. Methuen & Co. Limited, London.* 1942. 12*s.* 6*d.* net.

This is a masterly presentation of the essentials of entomology. It has been written with a selectivity arising from a marriage of ripe experience with great knowledge. It presents lucidly and attractively the facts needed for an elementary appreciation of the anatomy, physiology, and classification of insects, and of their place in evolution. The interest thus aroused will be stimulated by the admirable little essays on general subjects, which spring most naturally out of relevant sections and lead the inquiring mind towards the more fascinating problems of insect behaviour. The index is adequate, and paper and illustrations are excellent.

H.N.

WIRELESS RECEIVERS

Radio Receiver Design. Part I: Radio Frequency, Amplification, and Detection, *by K. R. Sturley. Pp. xii* + 435. *Chapman & Hall Limited, London.* 1943. 28*s. net.*

Dr Sturley's book forms a useful collection of the principles involved in radio frequency amplification and detection. Its name is somewhat misleading since, apart from a few charts, there is no emphasis on practical design details. This is noticeable when mathematical conclusions are left with scant mention of the implications. It is, on the other hand, a most valuable introduction to the subject for those interested in broadcast and communication receivers.

S. J.

EVOLUTION AND MORALITY

Science and Ethics, *by C. H. Waddington and others. Pp.* 144. *George Allen and Unwin Limited, London.* 1942. 7*s.* 6*d. net.*

Some time ago Dr Waddington wrote an article in *Nature* on "The relations between science and ethics" which led to a considerable discussion, and is reprinted here with comments from many sources. His thesis is, that the evolutionary process supplies us with a criterion of good, and that we need no other basis for morality. In some ways it reminds us of the Stoic doctrine of Deity evolving itself.

As the commentators point out, there seem to be discrepancies between the theory and the facts. Thus slavery, which was unknown among the earlier types of mankind, became universal in the civilizations of the ancient world; and therefore, according to Dr Waddington's criterion, slavery, being a principle developed by social evolution over a vast stretch of time, must be pronounced good. The Christian ethic, which frowned on slavery and eventually succeeded in abolishing it, was in fact completely opposed to the direction of the antecedent evolutionary process.

Much of the work of Dr Waddington and his critics reaches a high level and makes interesting reading; but one can imagine Burke saying, as he did of a similar attempt long ago, that he was 'not more than transiently amused with paradoxical morality.'

E.T.W.

पुस्तकालय गुरुकुल कांगड़ी विश्वविद्यालय हरिद्वार
CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

यह पुस्तक वितरित न की जाय
NOT TO BE ISSUED

सन्दर्भ ग्रन्थ
REFRENCE BOOK

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

Compiled
1999-2000

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri

CC-0. In Public Domain. Gurukul Kangri Collection, Haridwar

Digitized by Arya Samaj Foundation Chennai and eGangotri